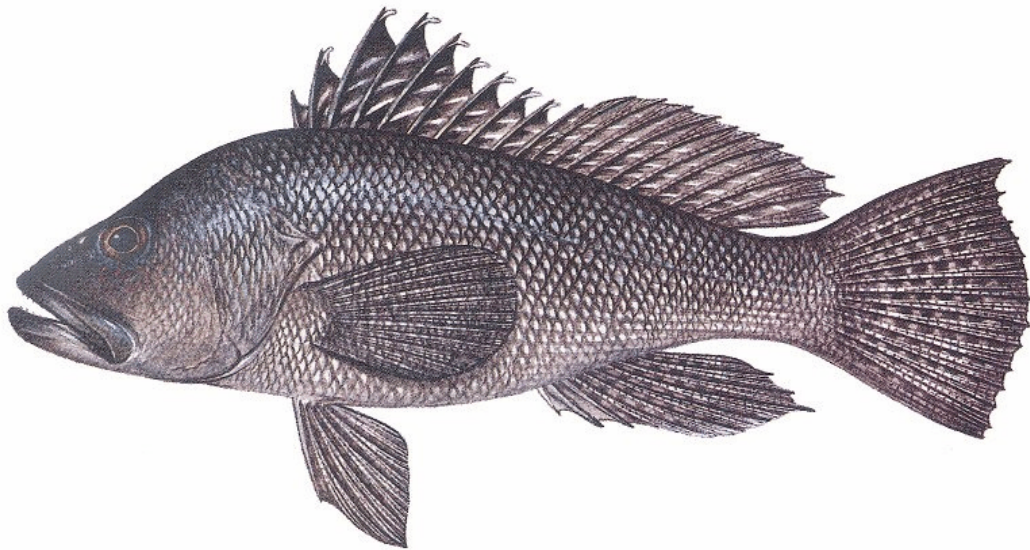


Report of Black Seabass Stock Assessment Workshop
Second SEDAR Process
Beaufort, North Carolina
January 6-10, 2003



Prepared for South Atlantic Fishery
Management Council
Charleston, South Carolina
14 February 2003

Executive Summary

The SEDAR II stock assessment workshop (AW) (*Appendix A*, Abbreviations and Symbols) was convened by the South Atlantic Fishery Management Council and NMFS Southeast Fisheries Science Center at the NOAA Center for Coastal Fisheries and Habitat Research, Beaufort, North Carolina on Monday, January 6, 2003. The AW's objectives were to conduct an assessment of the black seabass, *Centropristis striata*, stock off the southeastern U.S. and to conduct stock projections based on several possible management regimes (*Appendix B*, Terms of Reference). Participants in the workshop (*Appendix C*) included state, federal, and university scientists, as well as observers from the Council. All decisions regarding stock assessment methods and acceptable data were made by a consensus of participants.

Available data on black seabass included abundance indices and recorded data on landings, including size and age compositions of some landings and indices. Six abundance indices were developed by the preceding data workshop (DW): one from the NMFS headboat survey, one from the Marine Recreational Fisheries Statistical Survey (MRFSS), and four derived from the South Carolina MARMAP fishery independent monitoring program. The MRFSS index was dropped from most model runs because of concern by the AW that it was based on directed trips only. Landings data are available from all recreational and commercial fisheries. Abundance indices suggest that the stock declined between the 1980s and 1990s.

The AW applied both age-structured and age-aggregated models to available data. The age-structured model was considered the primary model, as recommended by the DW. Although there is considerable uncertainty in the application of these models, the status of stock depicted by these models is very consistent. That is, both model approaches depict a heavily exploited stock with considerable decline over the period examined. Based on the weighted mean results from a range of sensitivity runs of the age-structured model, the 2002 spawning stock size is estimated at about 22% of SSB_{MSY} while the 2001 fishing mortality rate is estimated at about 628% of F_{MSY} . Thus by standards of the Sustainable Fisheries Act and given the Council's usual definition of MSST as $(1-M)*SSB_{MSY}$, the stock is estimated at 30% of MSST, and therefore is overfished. Also F relative to F_{MSY} indicates that the stock is presently undergoing overfishing.

Stock projections were used to evaluate the level of F required to rebuild the stock to SSB_{MSY} and determine rebuilding time frames. Considerable reductions in fishing mortality from current levels are indicated by the suite of projections. To rebuild in the appropriate time frame, estimates of necessary reductions in F from current levels range from 50-90%, with the exception of one sensitivity run that indicated no rebuilding was necessary. Rebuilding duration ranged from 10 to 25 years, with the one exception. In the age-structured model, when fishing mortality is reduced to the rebuilding level, projected yields are initially lower than current levels, but exceed current yields within a few years.

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1 Place, time, and tasks

The SEDAR II assessment workshop (AW) (*Appendix A*, Abbreviations and Symbols) was convened at the NOAA Center for Coastal Fisheries and Habitat Research, Beaufort, North Carolina, by the South Atlantic Fishery Management Council (the Council) and the NMFS Southeast Fisheries Science Center (the Center). The AW met from 9:00 p.m. on Monday, January 6, to 12:00 noon on Friday, January 10, 2003. Participation in the workshop (*Appendix C*) included scientists from the states of Florida, North Carolina, and South Carolina; from NMFS laboratories and offices in Beaufort, Miami and St. Petersburg; representatives of the Council and its Scientific and Statistical Committee; and scientists from Virginia Polytechnic Institute and State University, including Dr. James Berkson, who chaired the AW.

The AW's major objectives were to conduct an assessment of the stocks of black seabass, *Centropomus striata*, and vermilion snapper, *Rhomboplites aurorubens*, off the southeastern US, and to conduct stock projections (*Appendix B*, Terms of Reference). In support of those tasks, the AW received data and recommendations from the data workshop (DW) that was convened in October 2002 by the Council and the Center. The DW was designed to be the first step in the assessment process, bringing together state, federal and university biologists with the needed expertise to decide which data were appropriate for use in the assessment. The AW was designed to follow the DW, with many of the same state and federal biologists participating. Some of the decisions regarding data made at the DW were refined during the AW. At both the DW and the AW, all decisions affecting the assessment were made by consensus of all participants. This report is concerned only with data and analyses for black seabass.

2 Stock and fishery characteristics

The following material is excerpted and expanded from the description of the stock and fishery in Hardy 1978; McGovern et al. 2002; Vaughan et al. 1995, 1996, 1998; Wenner et al. 1986.

2.1 Life History

The black seabass (BSB), *Centropristis striata*, is a protogynous serranid that occurs along the U.S. Atlantic coast from Cape Cod, Massachusetts, to Cape Canaveral, Florida, and in the Gulf of Mexico. Two populations, separated by Cape Hatteras, North Carolina, have been reported to occur along the Atlantic coast, although, genetic similarities suggests that this is one stock (Robert W. Chapman, pers. com.). Black seabass in the Gulf of Mexico are considered to be a separate subspecies. This assessment will focus on the stock unit south of Cape Hatteras, including fish from North Carolina (NC), South Carolina (SC), Georgia (GA), and the east coast of Florida (FL). Black seabass occur in depths of 2 to 120 m, but most adults are found in 20 to 60 m. Although black seabass north of Cape Hatteras are migratory, tagging studies indicate movements of black seabass south of Cape Hatteras are limited and less well-defined (Ansley and Davis 1981, Collins et al. 1996).

Black seabass spawn from January through July along the southeastern U.S. coast. Some spawning does occur in October-November, however, fall spawning is not observed every year. The greatest percentage of females in spawning condition occurs during March through May. Historic fecundity studies assumed that the number of eggs that were spawned was fixed prior to the spawning season (determinate spawning). Recent data show that black seabass probably recruit new eggs throughout the spawning season (indeterminate spawning), indicating that previous fecundity estimates should not be used for assessment purposes. Based on the presence of hydrated oocytes and post-ovulatory follicles, black seabass spawn every 3.4 days or 27 times during the 92 day spawning season (March-May). Fertilized eggs are round and clear with a diameter of 0.9 to 1.0 mm. Eggs are pelagic and hatch in 75 hours at 16°C and 38 hours at 23°C. Larvae are also pelagic and have been found in inlets, bays and offshore waters. Larvae become demersal at approximately 13-mm TL. Juveniles have been recorded from bays, estuaries, inlets and nearshore waters.

Black seabass are protogynous (changing sex from female to male). Individuals undergoing transition from female to male occur throughout the year, however, the percentage of transitionals is much lower during the spawning season and highest when spent and resting individuals are collected. According to McGovern et al. (2002): "Most black seabass undergoing transition were 160-259 mm SL (94%) and ages 2-4 (92%).” Males occur in all size and age groups, but are most frequent at sizes greater than 250 mm TL and ages of 4 and older. Black seabass live for at least 10 years.

2.2 Fisheries

Black seabass north of Cape Hatteras are managed as a separate stock by the MAFMC, black seabass south of Hatteras are managed by the SAFMC with a unit stock from Cape Hatteras to Florida. Three major fisheries catch this stock of black seabass: recreational, headboat, and commercial. Landings trends for black seabass for these fisheries are shown in Figure 2.1.

The recreational fishery is defined here to include all recreational fishing from shore, private boats, and charter boats (for-hire vessels that usually accommodate six or fewer anglers as a group). The recreational fishery uses hook and line gear almost exclusively. The recreational fishery shows high and quite variable values in the 1980's, peaking in 1984 at 1,014 mt (2.2 million pounds), and declining to lower and less variable values in the 1990's (averaging 300 mt, or 0.7 million pounds since 1990).

The headboat fishery (larger for-hire vessels that charge per angler) is sampled separately, and for that reason is distinguished here from other recreational fisheries. The headboat fishery also uses hook and line gear almost exclusively. Landings are initially high, peaking in 1982 at 334 mt (0.7 million pounds), then decline to lower values in the 1990's (averaging 85 mt, or 0.2 million pounds since 1990).

The most common commercial gear has been traps (or pots), with additional commercial landings from hook and line and trawling. Trawling for black seabass has been banned since January 1989 (SAFMC 1988) (Table 2.1). The black seabass commercial fishery peaked in 1981 at 543 mt (1.2 million pounds) and since then has fluctuated between 250 and 450 mt (0.6 to 1.0 million pounds) (Figure 1).

During the assessment time period (1978-2001), commercial trap landings peaked in 1981 (at 455 mt), but have generally averaged around 236 mt (0.5 million pounds) with little trend over the last 20 years (Figure 2.2). Commercial line landings have averaged about 90 mt (0.2 million pounds) with little trend, while the "other" category (includes trawl and miscellaneous gears) has averaged only 8 mt (0.02 million pounds), also with little trend.

During the early 1980's, before commercial data were available by species, the for-hire and recreational sectors contributed about the same amount to the black seabass catch and represented about 75% of the total. In recent years, the commercial catch and recreational landings are approximately equal (Figure 2.3).

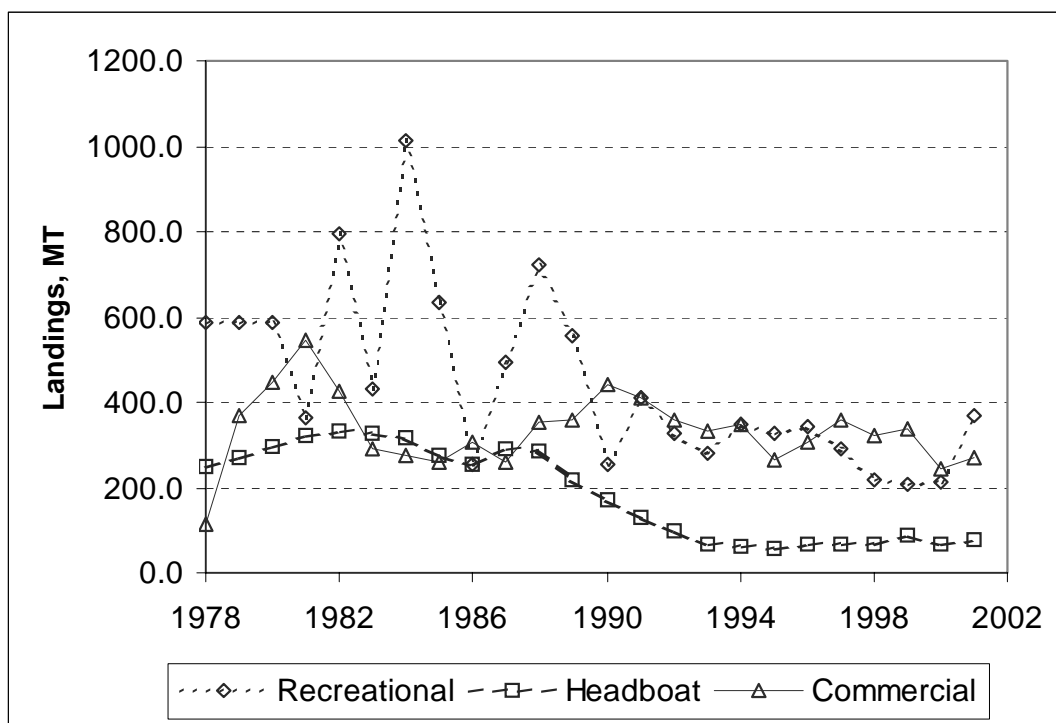


Figure 2.1. Landed catch (mt) of black seabass since 1978 by the 3 major fisheries.

Table 2.1. Black seabass regulation history.

Date	Amendment	Regulation
August 31 1983	Original FMP	8" TL minimum size limit and 4" trawl mesh size
January 12 1989	Amend. 1	Prohibits trawls
January 1 1992	Amend. 4	Prohibits fish traps, entanglement nets, and longline gear within 50 fathoms; black seabass pot gear and identification requirements
December 1998	Amend. 8	Limited entry program; transferable permits and 225-pound non-transferable permits
February 24 1999	Amend. 9	10" TL minimum size limit and 20 fish bag limit; escape panel

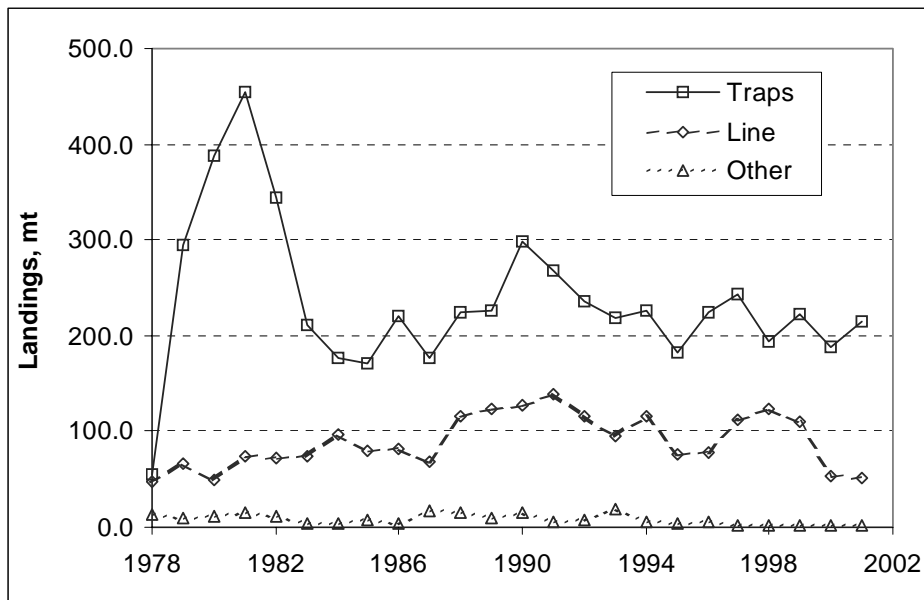


Figure 2.2. Black seabass commercial landings (mt) by gear.

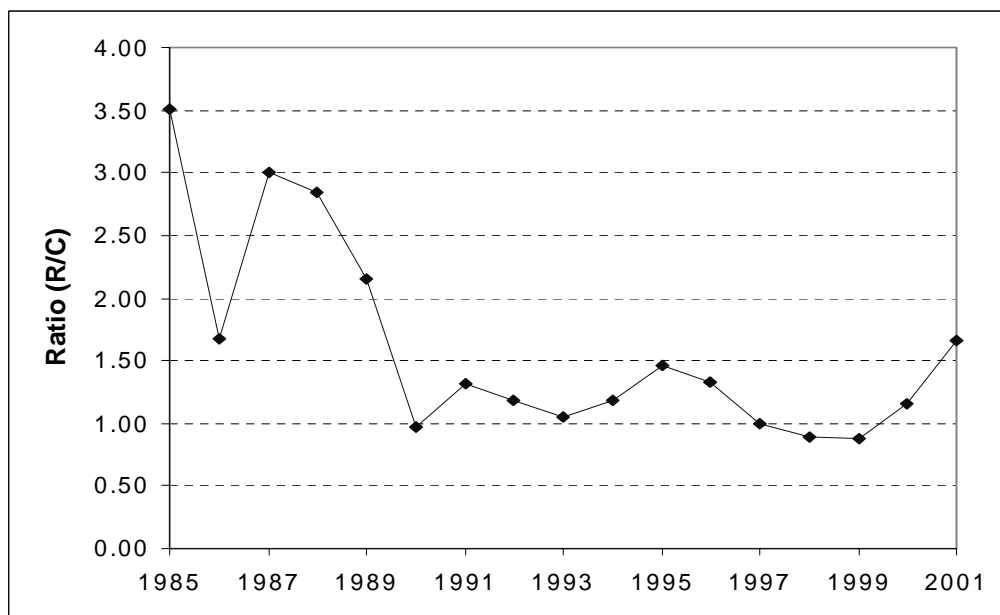


Figure 2.3. Ratios of recreational landings (including headboat) to commercial landings of black seabass.

3 Data workshop

Data for this assessment were prepared by a SEDAR-Data Workshop (SEDAR II - DW) that met for that purpose during the week of October 7, 2002 in Charleston, SC. Participants assembled into three working groups: life-history, recreational, and commercial. Each working group at SEDAR II - DW proposed recommendations on data to be used in this assessment, and then decisions regarding the recommendations were made by a consensus of all DW participants. Those recommendations are found in complete form in the documents of the Data Workshop and are summarized here. Additional questions that arose during initial model development and testing before SEDAR II-AW were resolved at AW (see Section 4). Furthermore, the DW concluded that the assessment modeling approach for black seabass and vermilion snapper should be the age-structured model. All DW recommendations described below were followed, except where indicated.

3.1 Findings of life-history working group

Unit stock The group agreed that black seabass in the South Atlantic Bight form a unit stock.

Age determination All ages used in the assessment were for black seabass sampled by MARMAP from 1978-1998. All black seabass sampled between 1978-1981 were aged. Since 1982 a subsample of 16-26 individuals per 20-mm SL size class from 120-200 mm SL were randomly selected and aged from each size class. All individuals larger than 200 mm SL or smaller than 120 mm SL were aged. About 400 fish were aged from each year for 1982-1998.

Natural mortality rate The group recommended a natural mortality rate $M=0.3/\text{yr}$ with a range of 0.2–0.4.

Release mortality The group recommended using an estimate of release mortality of 15% with a range of 10-20% (of fish caught and released) for all fisheries.

Maturity schedules Although there were temporal decreases in the size at maturity during 1979-1982 and 1983-1989 for fishery-independent blackfish traps, Florida snapper traps, and hook and line, the group recommended a single maturity schedule for each gear type for the entire period. Maturity schedules for 1990-2001 were based on chevron trap samples only.

Spawning-stock biomass The issue of how to compute spawning-stock biomass is complicated by the species' protogyny. The DW recommended performing the assessment with total spawning biomass, but considered the possibility of using only female spawning biomass.

Fishery-independent surveys The South Carolina MARMAP survey program, which has conducted reef-fish related sampling since 1979, is the only source of fishery-independent data. The group recommended four separate abundance indices for use in the assessment: a hook-and-line index (n=4,296), 1981-1987; a blackfish trap index (n=15,872), 1981-87; a FL snapper trap index (n=10,823), 1981–1987; and a chevron trap index (n=55,306), 1990–2001. The sample size, n, represents the number of fish lengths available from each gear type for the time frame given

3.2 Findings of recreational fisheries working group

Two sources of recreational information are available for use in the black seabass stock assessment: the National Marine Fisheries Service (NMFS) Headboat Survey and the NMFS Marine Recreational Fisheries Statistics Survey (MRFSS).

3.2.1 MRFSS

- DW recommended to split out headboat from MRFSS based on 1979-1985 intercepts by state (proportional to intercepts) for black seabass.
- DW recommended lumping the various MRFSS fisheries (shore-based, charter and private boats).
- DW also recommended post-stratification of black seabass catches from North Carolina (at Cape Hatteras) using intercepts to stratify effort from north and south of Cape Hatteras. In this way, the appropriate catch is obtained from multiplying respective effort by CPUE.
- DW recommended checking for missing mean weight of individual fish by cells (sorted by mode of fishing, year, state, 2-month wave, area) when converting MRFSS retained catch in numbers to retained catch in weight
- DW recommended against adjusting catches to include estimates for Monroe County, FL because these catches for black seabass were considered trivial and may include landings from Gulf of Mexico stock.
- DW recommended use of shore-based, private and charter boat estimates for black seabass. Likewise, DW recommended use of MRFSS measured mean weights from 1981-89 used for black seabass landings estimates for 1978-1980.
- The MRFSS CPUE data for black seabass were provided by MRFSS staff based on directed effort indicators. DW recommended consideration of these data in the assessment. The AW later dropped this index from the assessment (see Section 4).

- DW recommended incorporation of South Carolina supplemental intercept (length measurements of individual fish) data (1988-1995) for black seabass into the assessment.
- DW recommended weighting for individual lengths from MRFSS and South Carolina based on retained catch in numbers for MRFSS from 1981-2001 (by mode, state, wave, and area). Equal weightings were used for 1979-80 lengths. This recommendation was adopted for the assessment. Total samples size for 1979-2001 was 8,940 fish measurements.

3.2.2 Headboat

- DW noted that black seabass landings prior to 1976 were mixed with other seabasses and only reported from North and South Carolina, but since then landings are species specific and include expanded geographic coverage. Headboat landings for the assessment begin with 1978. Prior to 1981, black seabass landings were recorded only by weight, but since then landings are recorded in both numbers and weight. Mean weights for 1978-1980 were estimated by sampling area to convert catch in kilograms to catch in numbers by area, and then summed over area.
- DW recommended use of headboat CPUE in numbers/weight for black seabass. DW also recommended standardizing the headboat CPUE by delta-lognormal general linear model. Species-specific catch records for this analysis were available for 1973-2001. Categorical independent variables were year, month and area. (Because South Carolina inshore and offshore areas were combined by the survey personnel from 1988 on, a new area was defined for South Carolina from 1988-2001 for modeling.) The advantage of the delta-lognormal formulation is that it explicitly models both proportion of trips with nonzero catches and the catch per trip observed in those trips.
- DW recommended weighting for individual lengths from the headboat based on catch in numbers from 1978-2001 by sampling area and season.
- Total sample size of lengths from headboat biostatistical database was 101,943 fish.

3.3 Findings of the commercial fisheries working group

3.3.1 Landings issues

- The DW recommended separating North Carolina landings by management unit based on gear, with no trawl landings, 92% of trap landings, and all remaining gear-type landings assumed harvested in the Southern region.
- Historically, seabass were at times landed as mixed species under ‘seabass unclassified’ category.
- Based on trip ticket reports from Florida (1995-2001) and North Carolina (1994-2001), early period mixed seabass landings are adjusted by the percentage of black seabass to other seabasses from recent time period. The adjustment for North Carolina is 99.8%; and for Florida it is 98%.
- South Carolina landings were reported to species and are generally considered free of bias due to species mixing. There is no monitoring of other seabass species or sampling beyond the basic TIP requirements available to test this assumption.
- Georgia landings data were available only through the NMFS website. No adjustments were made.
- Commercial landings of black seabass are available since 1950. Between 1950 and 1983 data were collected through the NMFS General Canvass, and coverage was incomplete and variable across states and years. The TIP program began in 1984 and expanded the dealer coverage for landings records over the General Canvass. North Carolina instituted mandatory reporting in 1994 with their Trip Ticket Program; Florida instituted mandatory reporting in 1985, but did not become official landings until 1986.
- Landings can be condensed into three categories: Traps (pots and traps), Lines (hook and line, electric reels, longlines, trolling), and Other (gill nets, trawls, gigs, spears etc). Trap and line categories represent 95% of the total landings on average for 1972 – 2001 and 99% of the total landings since 1997.

3.3.2 Length Distributions

- The TIP program also included length sampling. NC and FL collect length samples beyond the TIP targets.

- Length measurements are based on total length (TL). Landings from SC in some years coded as fork length (FL) are measured as the center line of the tail and are treated as TL measurements without conversion (assumed coding error because black seabass have no fork).

- Length frequencies were tabulated annually in 10 mm length categories, from 100 to 500 mm.

- Sample sizes for length data from all sources are shown in Table 3.1. Length distributions by year are shown in Figure 3.1 and Figure 3.2.

Table 3.1. Sample sizes of length data from fishery-independent and fishery dependent sources.

Year	MARMAP				Commercial			Recreational	
	Hook-and-line	Blackfish trap	FL snapper trap	Chevron trap	Traps	Hook-and-line	Trawl+ other	Headboat	MRFSS
1978								2357	
1979								1655	361
1980								2420	158
1981	439	1772	1088					3035	194
1982	728	1671	2423					3686	417
1983	950	3384	1378					5734	173
1984	694	2860	1760		870	1453	29	6091	285
1985	680	2972	1798		654	1124	14	5860	488
1986	411	1719	1444		41	1393	968	6551	380
1987	394	1494	932		761	1274	34	6443	668
1988					1260	981	304	4256	595
1989					369	706	15	3836	651
1990				6771	770	1256	201	6200	417
1991				4105	1172	1684	157	5381	223
1992				4667	1482	1450	26	5186	612
1993				4544	395	1144	783	3941	349
1994				4772	1019	997	680	4215	323
1995				4518	218	600	338	3325	314
1996				3698	213	713	376	3212	315
1997				4324	935	1009	261	3678	306
1998				4324	428	1638	54	4365	357
1999				4779	868	1749	2	4114	419
2000				4589	448	1083	173	3419	367
2001				4215	587	1880	417	2983	568

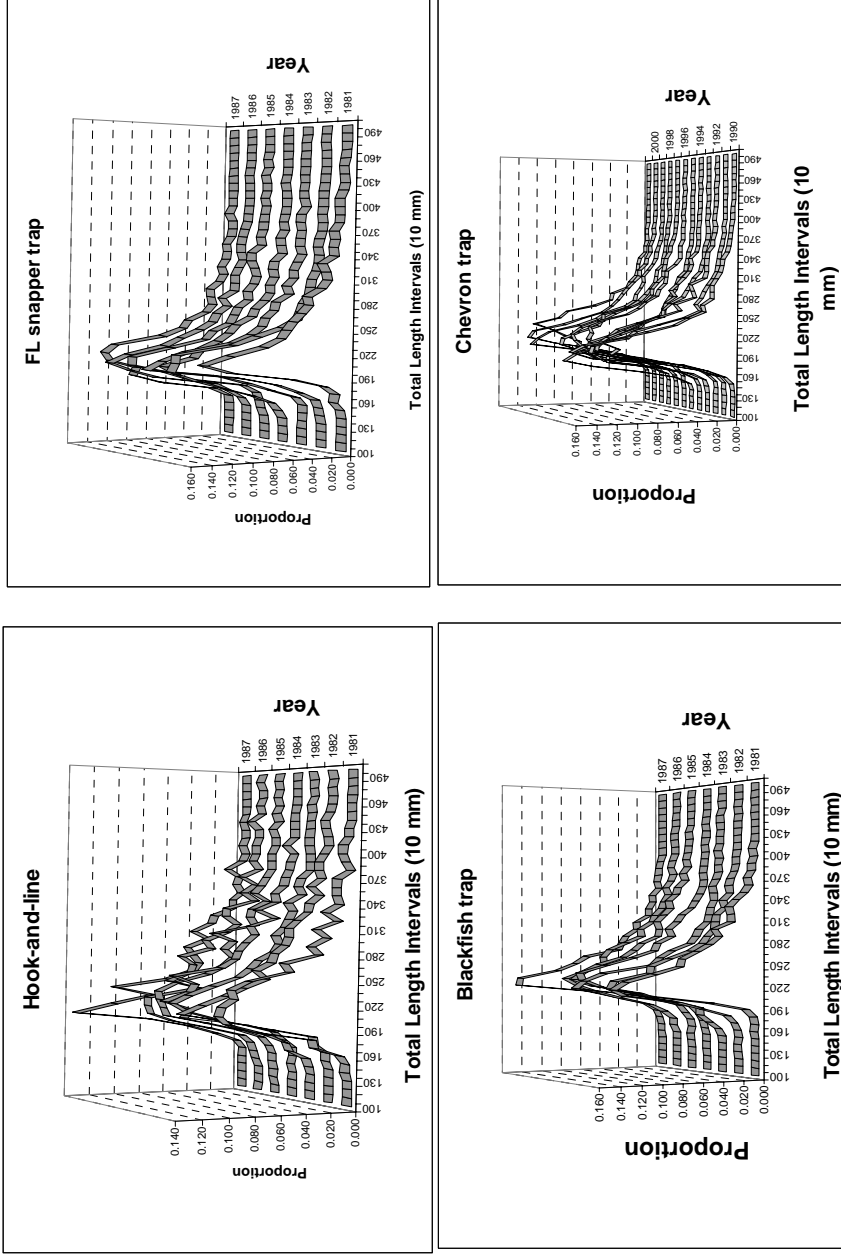


Figure 3.1. Length distributions from fishery-independent sources (MARMAP).

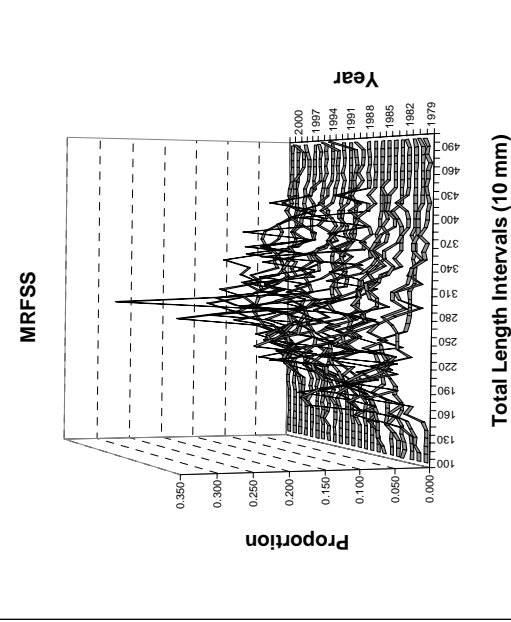
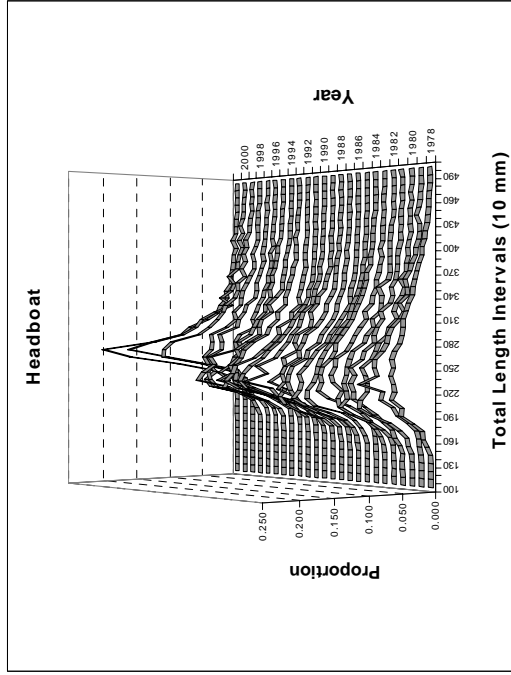
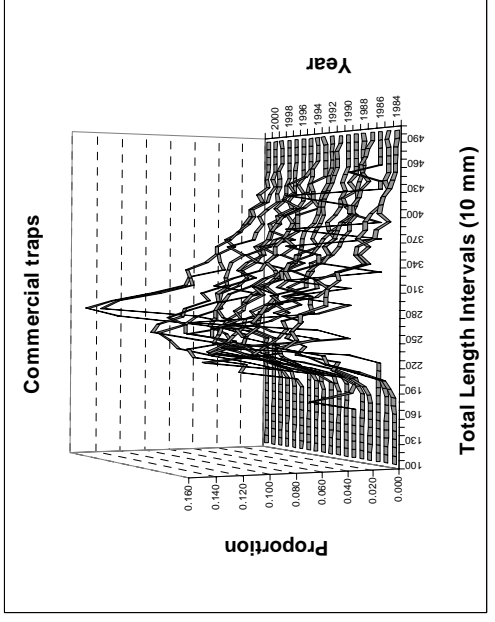
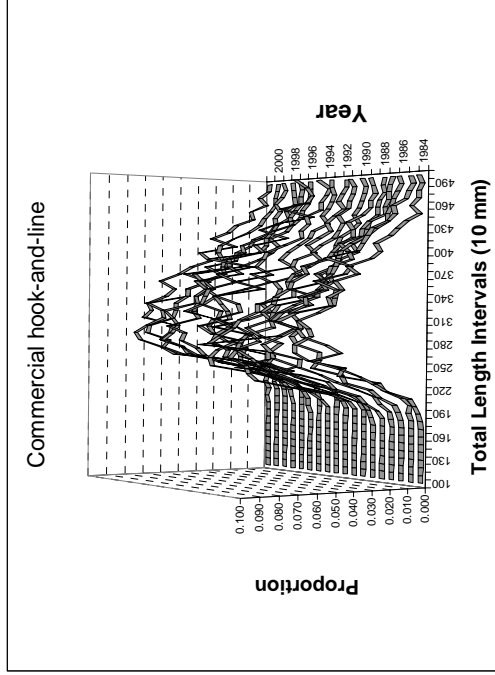


Figure 3.2. Length distributions from fishery-dependent sources.

4 Data issues resolved at the Assessment Workshop

AW considered additional data issues that arose during development and preliminary application of the age-structured assessment model. A brief description of those issues and the resolution chosen by the AW follows.

4.1 General data issues

- AW decided to run the age-structured model at the intermediate natural mortality value, $M = 0.3$, and to make sensitivity runs at $M = 0.2$ and $M = 0.4$.
- AW selected a fixed sex ratio based on pooled trap and hook & line MARMAP data ($n=11,015$). Female maturity was estimated for three time periods reference by the DW from pooled trap and hook & line MARMAP data (1978-82: $n=3,023$; 1983-89: $n=965$; and 1990-01: $n=1,289$). Sex ratios and female maturity schedules are summarized in Table 4.1. AW recommended that all males age 1 and older be considered mature.
- The AW selected parameters for the von Bertalanffy growth function estimated by McGovern et al.: $L_{\infty} = 398$ mm SL, $K = 0.16$, and $t_0 = -1.29$. The estimate of L_{∞} was converted from SL to 526.5 mm TL based on relation given in McGovern et al. (2002).
- AW recommended use of a weight-length relationship developed from headboat data with sample size ($n=103,019$ from 1975-2001): $W = \exp(-16.932 + 2.79 \cdot \ln(TL))$.
- AW decided to run the age-structured model at the intermediate value (0.15) of release mortality.
- AW selected the delta-lognormal standardized CPUE for application with Headboat data from 1973-2001 for this assessment.
- Fish lengths were aggregated into 10 mm bins (size categories) for all fisheries.
- AW decided to structure the age-based assessment model in a manner that accounted for fishery management changes over the history of the fishery. AW decided to model the effects of management change by estimating different fishery-specific selectivities. By modeling changes in selectivity, the model will respond to management measures, such as changes in size limits, that affect the length distribution of the landings. These time periods were 1978-1982, 1983-1998, and 1999-2001.
- The data workshop participants recommended using a suite of relative abundance indicators for the assessment. These are shown in Figure 4.1. After further discussion of the analytical approach for standardization of the MRFSS CPUE data, the AW participants decided that further research into the use of targeting measures from these data was warranted. The AW noted that the divergence in pattern observed between

MRFSS and the Headboat and Chevron trap indices (Figure 4.1) could be explained by inadequate analytical treatment of targeting effects in the MRFSS data. For this reason, the AW decided to eliminate the MRFSS index from the base assessment model applications for black seabass.

Table 4.1. Estimated weight of black seabass, proportion female and female maturity at age based on life history sample collections and applied in the assessment model. Weight for age 0 is estimated at mid-year, while weight for older ages is estimated at start of year (calculated from weight-length relation and von Bertalanffy growth equation).

Age	Weight (kg)	Proportion female	Female maturity		
			1978-1982	1983-1989	1990-2001
0	0.04	1	0	0	0
1	0.06	0.87	0.56	0.98	0.83
2	0.14	0.75	0.89	1	0.93
3	0.25	0.44	0.99	1	0.99
4	0.36	0.29	1	1	1
5	0.49	0.13	1	1	1
6	0.61	0.05	1	1	1
7	0.74	0.02	1	1	1
8	0.85	0	1	1	1
9	0.96	0	1	1	1
10	1.06	0	1	1	1
11+	1.14	0	1	1	1

- AW used abundance indices in weight per unit effort for the production model (lumped biomass), for consistency with model assumptions.
- The recreational hook-and-line fisheries (MRFSS and headboat) were assumed to have the same selectivity to simplify modeling and relatively low sample size from the MRFSS.
- DW recommended computing spawning-stock biomass based on two different measures: total mature biomass (preferred) and mature female biomass (as a sensitivity

run). The interpretation of these analyses continues to be problematic, as the relative importance of males and females to population spawning success is not known.

- Aging data for fishery-independent (MARMAP) samples were excluded, as specimens had not been randomly selected for aging, but rather to provide detail in all length classes for use in age-length keys. The resulting age-composition estimates were therefore not representative of the entire sample and were considered inappropriate for use as age-composition data with this model.

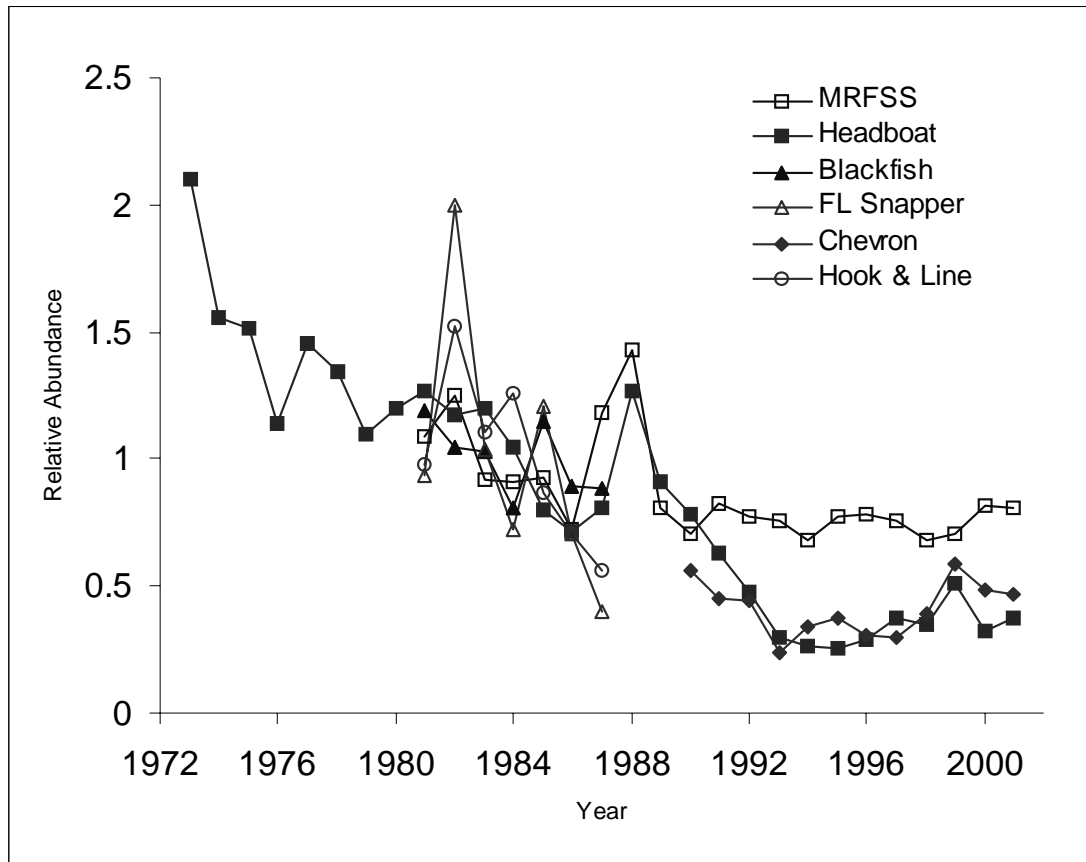


Figure 4.1. Comparative patterns of relative abundance estimated from the data sources indicated. Values are scaled to the means of the individual time series during the period 1981-1987, with the exception of the Chevron series, which is scaled to the mean of the rescaled Headboat time series from 1990-2001.

4.2 Stock-recruitment curve

The model uses a Beverton-Holt stock recruitment curve of the form that includes a parameter for steepness and a parameter R_0 representing the theoretical level of recruitment in an unfished equilibrium state. Both parameters strongly influence estimates of management benchmarks. Consequently, a range of values for steepness (detailed in section 6.1.1) was examined for its effect on model results and R_0 was constrained to biologically reasonable values.

4.3 Additional constraints

Additional constraints were placed on the model to maintain biologically reasonable solutions. Constraints took the form of penalties added to the total objective function.

- Deviations of estimated recruitments from the estimated stock-recruitment model were penalized.
- Recruitment deviations in the model initialization period carried an extra penalty. The initialization period (1967-1977) was required to provide estimates of numbers at age in the first model year (1978).
- Recruitment in the first year of the initialization period was constrained to follow the estimated stock-recruitment curve.
- Recruitment deviations from the estimated stock-recruitment curve in the final three model years (least complete cohorts) were penalized.
- Variances of size-at-age were constrained to ensure that estimates for adjacent ages were similar.
- Full Fs in the final five model years were penalized for deviation from each other.
- Double-logistic selectivities were constrained to be realistic by adding a penalty if the declining slope of older ages was very steep.
- As described in section 6.1.3, several model runs required two additional constraints: one on R_0 and one on full F. A penalty was added if R_0 was greater than twice the mean of recruitments estimated in the first three years (1967-1969). A penalty was added if full F in any year was greater than five.

5 Description of assessment models

5.1 Age-structured model

5.1.1 Properties of age-structured model

The forward-projecting statistical age-structured model for this assessment was implemented in the AD Model Builder software (Otter Research 2000) on a microcomputer. The specific model formulation and implementation used in this assessment is here designated BSB2003. The formulation's major characteristics can be summarized as follows:

Natural mortality rate The natural mortality rate was assumed constant over age and time.

Stock dynamics The standard Baranov catch equation was applied. This assumes exponential decay in population size due to fishing and natural mortality processes.

Growth A von Bertalanffy growth model, constant over time, was fixed according to the relationship given in McGovern et al. (2002). Distribution of lengths at age were assumed normally distributed, with mean based on the growth model and variance estimated.

Recruitment A Beverton–Holt recruitment model was estimated internally. Estimated recruitments were loosely conditioned on that model.

Biological benchmarks The benchmarks F_{MSY} and SSB_{MSY} were estimated internally by the model using the method of Shepherd (1982). In that method, the point of maximum yield is identified from the recruitment curve and other biological parameters, such as those for growth and maturity. Selectivity at age must also be specified; here, the model incorporated the catch-weighted selectivities at age estimated for the last three years (1999–2001), a period of unchanging regulations.

Fishing Five fisheries were modeled individually: commercial hook-and-line, commercial traps, commercial other; recreational headboat, and recreational (shore-based, private and charter boats). Separate fishing mortality rates were estimated for each fishery.

Selectivity functions Selectivity was fit parametrically, using a logistic model or double-logistic model (MARMAP trap gear), rather than estimating independent selectivity values for each age. That approach reduces the number of estimated parameters and imposes theoretical structure on the estimates.

Selectivity of fishery-dependent gear Each fishery is assumed to have constant selectivity during each period of constant regulation. Commercial other, the least substantial fishery, was assumed to have constant selectivity across regulation periods. That assumption was relaxed for the remaining fisheries (commercial trap, commercial hook-and-line, headboat, and MRFSS) by allowing selectivity to vary with changes in regulations. The selectivity vectors are estimated internally by BSB2003.

Selectivity of fishery-independent gear The four fishery-independent abundance indices are assumed to have individual time-constant selectivity vectors; the corresponding selectivity vectors are estimated internally by BSB2003.

Discards Discarded fish are routinely estimated in the MRFSS and are accounted for in the estimate of total landings in the model. However, no discard information was made available for any of the other fisheries by the DW. An approximate measure of the discards from commercial hook-and-line, commercial trap, and headboat fisheries, which account for the majority of landings, was modeled with separate selectivity curves. The discard selectivity curve was estimated as the greater of zero or the difference between selectivity before and after size regulations, which represents likely discards of under-sized fish during the periods of size regulation. This is viewed as an underestimate of discards, because the implicit assumption is that no discarding occurred before the size regulations were in place, and that discards only result from the size limit. Any regulation, such as trap escape vents, that reduce size based discards are not specifically modeled.

Discard mortality rates were then estimated by assuming release mortality rates of 0.15, as recommended by DW. The product of release mortality, the estimate of fishing mortality rate, and the estimated discard selectivity curve provided age-specific instantaneous discard mortality rates.

Abundance indices The model used four separately modeled indices of abundance, as described above. They were three fishery independent indices (hook-and-line, 1981-1987; blackfish trap, 1981-1987; FL snapper trap, 1981-1987; and chevron trap, 1990-2001) and one fishery dependent index (headboat, 1973-2001).

Fitting criterion The fitting criterion was a total likelihood approach in which total catch was fit almost exactly, and the observed age- and length-compositions, as well as the abundance index patterns, were fit to the degree that they are compatible. Landings data and abundance index data were fit using a lognormal likelihood, the value of which is inversely related to the coefficient of variation (CV). CVs of abundance indices were provided or calculated; CVs of landings data were assumed equal among fisheries (CV=0.05). Composition data were fit using a multinomial likelihood. In addition, penalties were added to the total likelihood for deviation from realistic biological or fishery characteristics (e.g., recruitments or F 's fluctuating greatly from year to year). Relative statistical weighting of each likelihood component for the central case was chosen by the AW after examining many candidate model runs. The criteria for choice

were a balance of reasonable fit to all available data and a good degree of biological realism in estimated population trajectory.

5.2 Age-aggregated production model

The age-aggregated production model used was the Graham–Schaefer logistic surplus-production model (Schaefer 1954, 1957; Prager 1994) . This is a continuous time formulation, conditioned on catch, that does not assume equilibrium conditions. By conditioning on catch, the landings data are assumed more precise than the abundance indices. The model fits more than one abundance index by assuming they are correlated measures of stock abundance and that differences between indices can be considered sampling error.

One form of the production model was fit: the Schaefer (1954; 1957) model, which assumes $B_{MSY} = 0.5K$, where K is the carrying capacity of the stock (virgin stock size). The Schaefer form is often used as a default because of its theoretical simplicity and because it is considered a central case among possible shapes of production model. To fit the production models, a revised version of the ASPIC software of Prager (1995) was used.

Three applications of ASPIC were made using the extended landings for 1950-1977 presented in Section 2. Three assumptions were evaluated concerning the level of recreational landings relative to commercial landings during the period for which recreational landings data were not available (Figure D.2). These assumptions were that recreational landings were equal to commercial landings ($R=C$), 2 times commercial landings ($R=2C$), and 3 times commercial landings ($R=3C$). The AW recommended that the middle assumption ($R=2C$) be considered the base run.

6 Model application and results

6.1 Age-structured model

6.1.1 Description of central run and matrix of sensitivity runs

A large number of preliminary runs of the age-structured model were made. A central run was chosen by the AW based on a suite of residual pattern diagnostics. The central run used the data from the Data Workshop with all adjustments described above. The AW was concerned that model predicted uncertainty in the central assessment run would tend to underestimate the uncertainty in the assessment, especially relating to key parameters such as natural mortality rate and steepness in the stock-recruit relationship.

Because of these concerns, eight additional runs were chosen to examine sensitivity of results to these two key parameters. The AW decided to use the range of results from the central run and a matrix of sensitivity runs upon which to base status of stock and to characterize uncertainty in the assessment, rather than to adopt a single run as best representing the condition of the stock. Based on the results of Rose *et al.* (2001), the AW defined a range of steepness values from 0.4-0.8, values which capture the main part of the distribution of steepness estimated for life history strategies similar to black seabass. Steepness (h) was fixed at an endpoint of the Rose *et al.* range, or else was estimated internally (labeled “free”). The range in natural mortality rate ($M = 0.2, 0.3, 0.4$) and range in steepness ($h = 0.4, \text{free}, 0.8$) resulted in a 3x3 matrix representing uncertainty in the assessment. A set of marginal probabilities were assigned by consensus of the AW to M (0.25, 0.5, 0.25) and to h (0.25, 0.5, 0.25) based on a triangular distribution giving more weight to the central value compared to smaller but equal weights to each tail. The probabilities for each cell were based on the product of these marginal probabilities (e.g., $M = 0.3$ and steepness = 0.4 has a probability associated with it of $0.5 \times 0.25 = 0.125$ as in Table 6.1 below).

Table 6.1. Sensitivity runs for natural mortality (M) and steepness (h) and their AW-designated probability weightings.

			Steepness (h)		
			0.4	Free	0.8
		Marginal Probability	1/4	1/2	1/4
Natural mortality (M)	0.2	1/4	1/16	1/8	1/16
	0.3	1/2	1/8	1/4	1/8
	0.4	1/4	1/16	1/8	1/16

Hence, this “central run” is not considered to be a “base run” as typically used. It is simply the most likely as represented by the cell probabilities (0.25) given in Table 6.1, and results from the central values ($M=0.3$ and $h=\text{free}$) of the marginal distributions having greatest probability. The AW recommended that overall status of the stock be determined from a weighted average of a given status variable from each cell in the above 3x3 matrix.

Sensitivities to other model assumptions and parameter assignments were also examined as variations of the central run. These variations are: 1) SSB based only on females, 2) SSB based only on females with steepness fixed near that estimated by the central run, 3) MRFSS CPUE included, and 4) an alternative likelihood weighting scheme along with growth parameters estimated internally.

Uncertainty predicted by the model only reflects uncertainty in the fit of the model to the data. Uncertainty illustrated in the sensitivity runs only reflects uncertainty in those parameters that are varied. What can not be directly evaluated are errors resulting from the assumptions needed to develop the full data input and inadequacies in the input data series, such as poor temporal coverage of fishery-independent surveys, insufficient biological sampling of the fisheries, and incomplete tabulation of total removals by the fisheries.

6.1.2 Results of central run

The model was configured to match observed catches almost exactly (Figure 6.1 and 6.2). Fits of the central run of the BSB2003 model to the abundance indices are shown in Figures 6.3 and 6.4. Reasonably good fits were found to the blackfish and chevron trap indices. The Florida snapper trap and MARMAP hook-and-line indices are highly variable with little trend, patterns which the model fits poorly. The headboat index, a long time series with pronounced trend, is fit quite well by the model.

Selectivities of the four major fisheries are shown in Figure 6.5. Selectivities estimated from the headboat and recreational fisheries show a slight shift towards larger, older fish with the imposition of minimum size limits in 1983 (8" TL) and 1999 (10" TL). The selectivity for commercial trap and lines was initially around age 3 for the first period (1978-1982) when there was no minimum size limit. During the second period, when the 8" TL minimum size limit was in effect, a lower selectivity was estimated for both gears. In the final period (1999-2001), when the 10" TL minimum size limit was in effect, the commercial traps showed only minimal increase in selectivity at age, while the commercial lines showed an increase in selectivity back to a level similar to the first period.

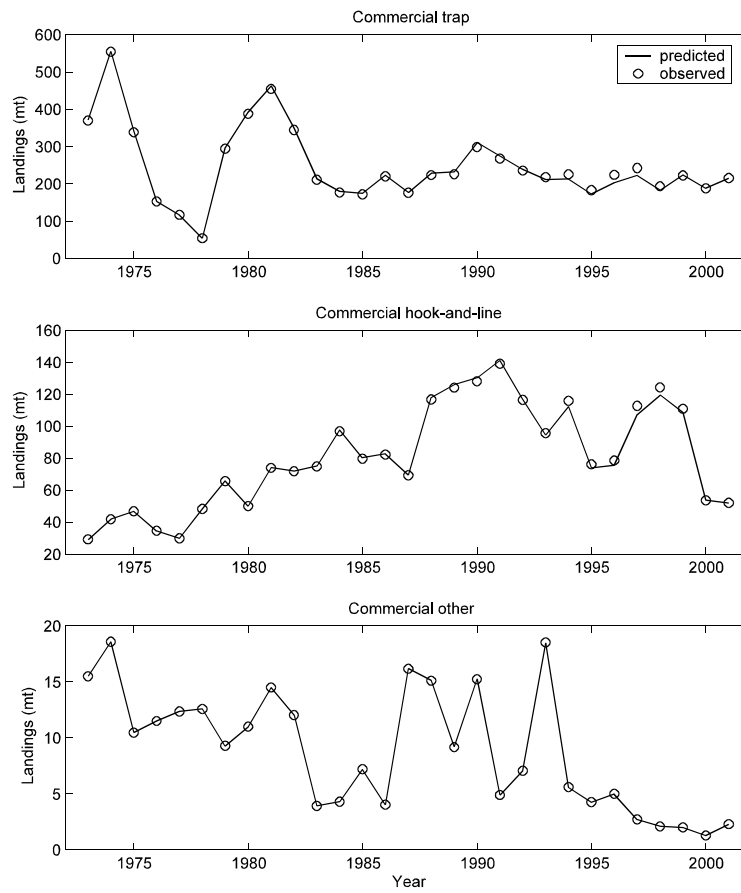


Figure 6.1. Observed (circles) and predicted (lines) commercial landings from central run of BSB2003.

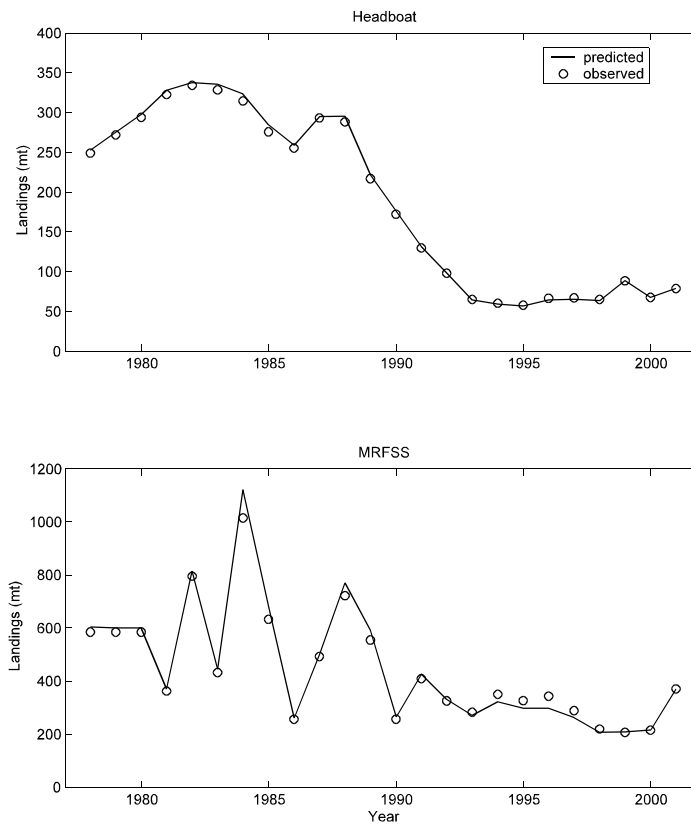


Figure 6.2. Observed (circles) and predicted (lines) recreational landings from central run of BSB2003.

Discards are estimated for headboat and commercial landings based on the change in selectivity relative to the first time period. Because higher selectivity was found with the commercial gears (trap and lines) for the first period relative to the later periods, no discard is estimated.

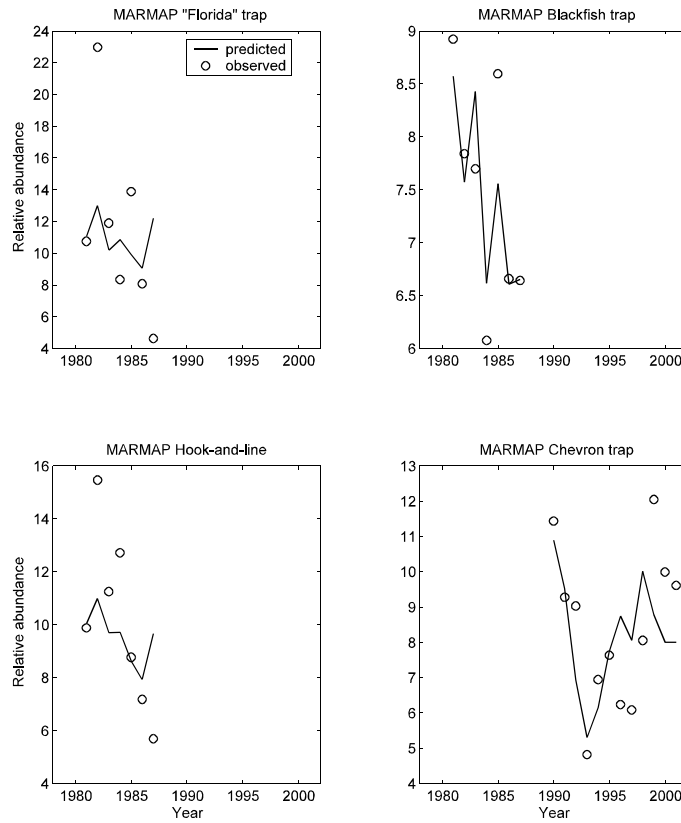


Figure 6.3. Observed (circles) and predicted (lines) fishery independent abundance indices, from central run of BSB2003.

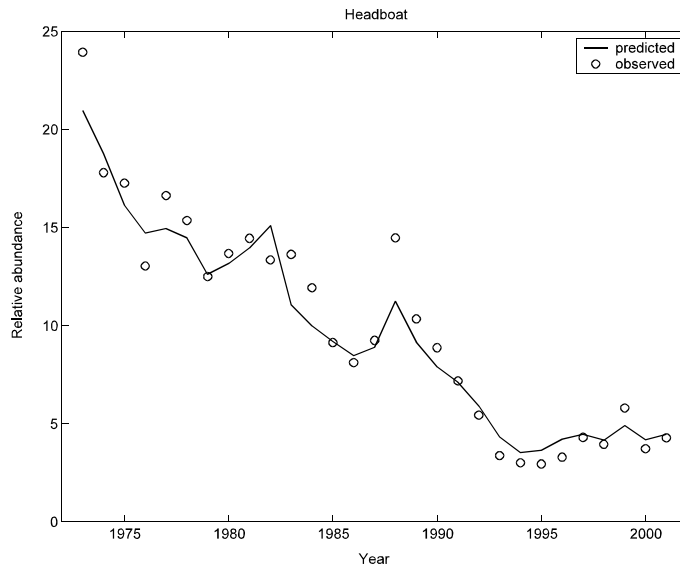


Figure 6.4. Observed (circles) and predicted (lines) fishery-dependent abundance index, from central run of BSB2003.

Based on the central run, the model estimates that SSB (mature biomass) had declined to about 30% of its 1978 value by 1995, and remaining low through 2002 (Figure 6.6). Values of SSB in the early years of the assessment were at or above 4000 mt, and declined sharply in the early 1990s to values generally below 2000 mt.

The model estimates that resulting recruitment has declined to about 55% of its average 1978-85 level (averaging 10.3 million seabass) in the recent period (1995-2001, averaging 5.7 million seabass) period. The decline in estimated recruits precedes the decline in estimated SSB.

The estimated stock–recruitment relationship shows the usual scatter about the fitted Beverton–Holt recruitment curve (Figure 6.7). The ranges of SSB and resulting recruitment in this table are less than those suggested at MSY ($SSB_{MSY} = 13,518$ mt and $R_0 = 27$ million). This implies that the stock during the assessment period has been low relative to its potential. Note that benchmarks change with changing overall selectivity of the fishery. Estimates of benchmarks presented in this report are based on selectivity from the final time period (1999-2001) when selectivity was assumed constant across fisheries.

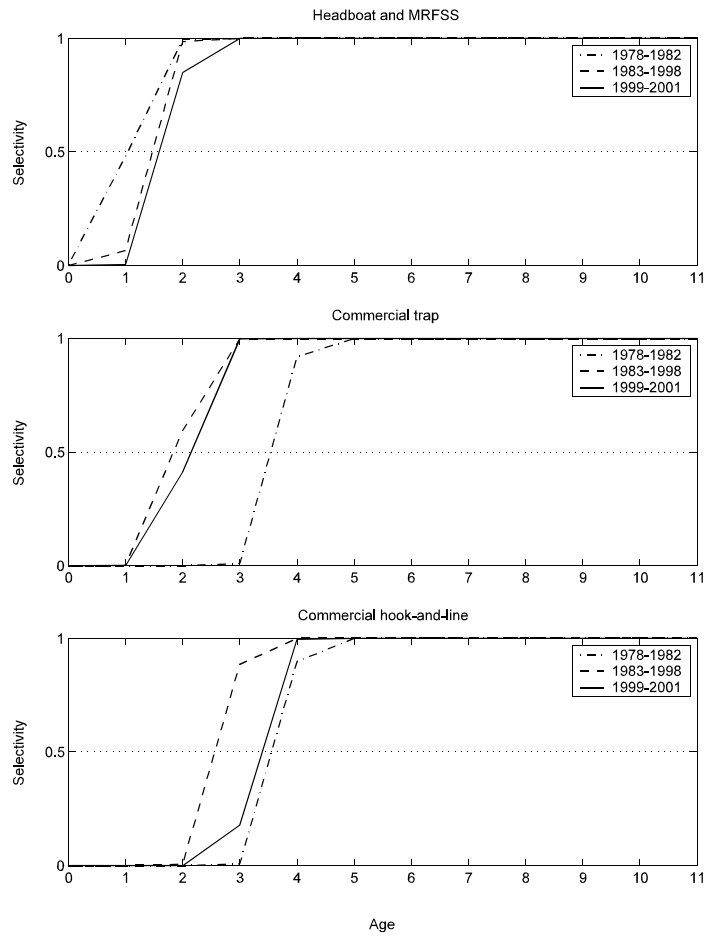


Figure 6.5. Estimated selectivity for the central run of BSB2003 by fishery over time.

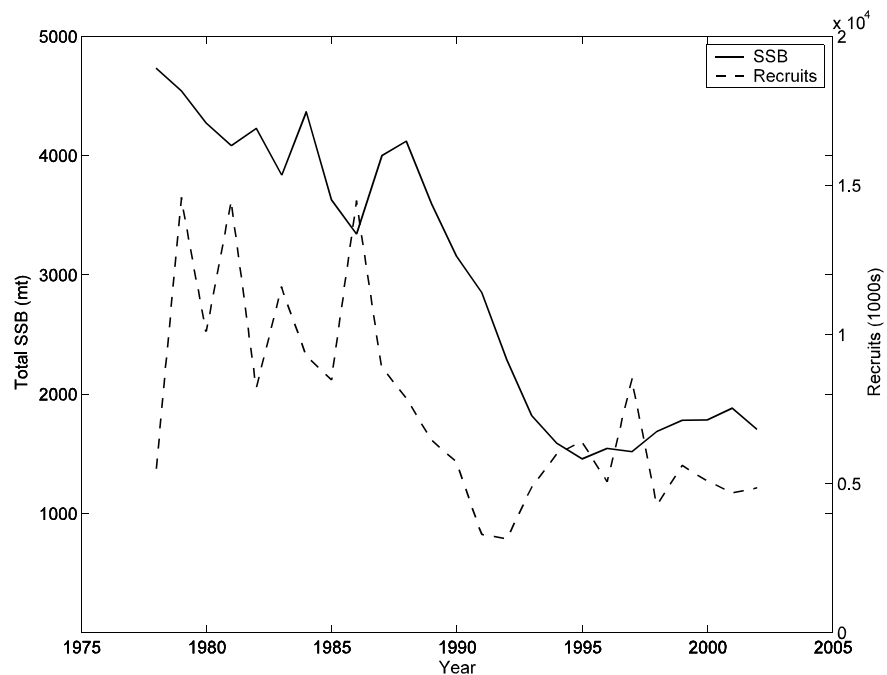


Figure 6.6. Estimated time trend of mature biomass and age 0 recruits of black seabass over the period 1978-2001 from the central run of BSB2003.

These results are consistent with the existence of a substantial fishery for black seabass in the 1960's as evidenced by the landings data shown in Appendix D. The model, however, does not directly consider the more historical landings and for that reason, the estimates relative to benchmarks could differ if more historic landings data were incorporated.

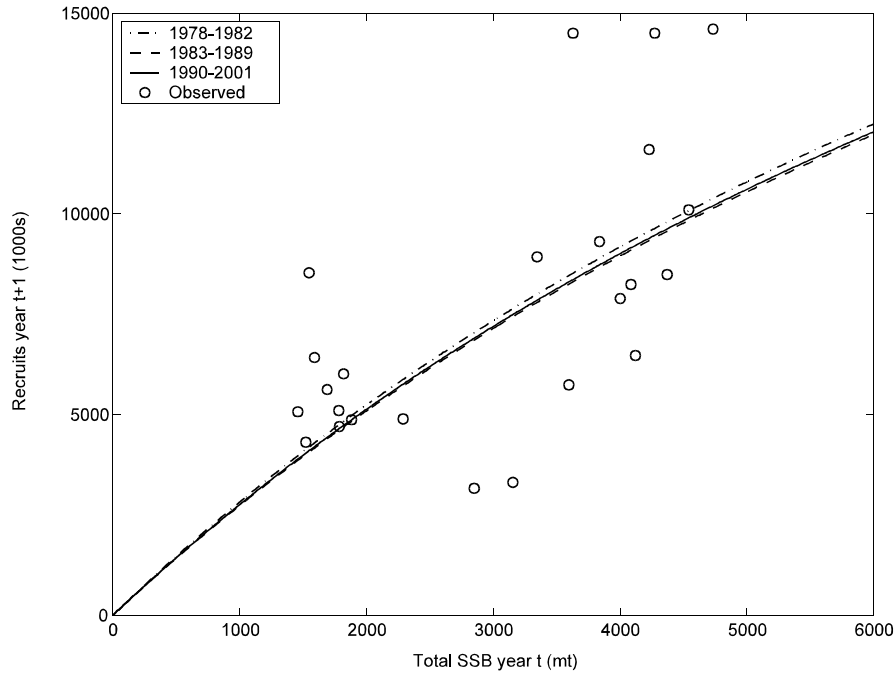


Figure 6.7. SSB and recruitment of black seabass estimated from the central run of BSB2003 with estimated Beverton–Holt recruitment model. The three curves correspond to time periods of different female maturity schedules: 1978-1982, 1983-1989, 1990-2001.

Fishing mortality rate relative to F_{MSY} is fairly constant until about 1993, at which time it increases sharply, peaking in 1999 at about 10 times F_{MSY} (Figure 6.8). Fishing mortality F in 2001 is estimated to have been reduced to about 5 times F_{MSY} . Spawning stock biomass relative to SSB_{MSY} at the start of the assessment period is about 35%, and declines during the early 1990s to about 11% in 1995, with some small improvement since then to about 13% in 2002.

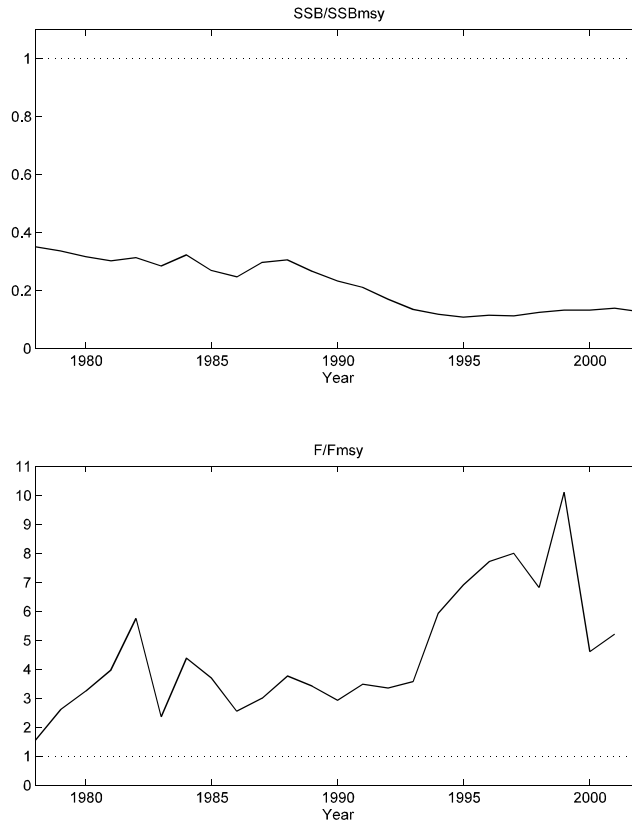


Figure 6.8. Time-trajectories SSB/SSB_{MSY} and F/F_{MSY} from the central run of the age-structured assessment model.

6.1.3 Results of sensitivity and alternative runs

Sensitivity runs were made based on the matrix of values for natural mortality (M) and steepness (h) as described in Section 6.1.1. Results of the various assessments of black seabass are tabulated in Table 6.2 and summarized in the form a schematic fishery control rule (Figure 6.9). The suite of sensitivity runs show a wide range of values for various benchmarks and other variables. F_{MSY} varies from 0.09 to 0.99 with the central value of 0.20 and weighted mean value of 0.27. SSB_{MSY} varies from 3,050 mt to 38,300 mt with the central value of 13,500 mt and weighted mean value of 14,500 mt. Other variables in Table 6.2 also show a wide range with central values similar to weighted mean values. Both central and weighted means suggested the stock is overfished (SSB/SSB_{MSY}) and overfishing (F/F_{MSY}) is occurring.

In the control rule plot (Figure 6.9), F/F_{MSY} is plotted against SSB/SSB_{MSY} with thresholds and targets shown on the same plot. The fishing mortality control rule (MFMT) is defined so that for SSB greater than $MSST$ ($= (1-M)SSB_{MSY}$), then $MFMT = F_{MSY}$; and for SSB less than $MSST$, then $MFMT = F_{MSY} * SSB/MSST$, or line drawn from the origin to the point (F_{MSY} , $MSST$). Virtually every run shows that the stock is overfished and overfishing is occurring. The only exception is the sensitivity run where $M=0.4$ and $h=0.8$. That single run suggests a species that is highly resilient to fishing.

Table 6.2. Summary of estimates from central age-structured model and sensitivity runs. Asterisk () indicates additional constraints required for optimization procedure (full $F \leq 5$ and $R0 \leq 2$ times mean recruitment from first three model years). Weighted mean of F_{max} uses 2.0 for values greater than 2.0.*

	Fmsy	F0.1	Fmax	MFMT	SSBmsy	MSST	MSY	F(2001)/ Fmsy	SSB(2002)/ SSBmsy	steepness (h)	R0
M=0.2, steep=0.4*	0.09	0.19	0.40	0.002	3.83E+04	3.07E+04	2.63E+03	22.23	0.02	fixed	3.43E+07
M=0.2, steep=free*	0.20	0.19	0.40	0.01	2.53E+04	2.02E+04	3.58E+03	9.51	0.06	0.67	2.73E+07
M=0.2, steep=0.8*	0.26	0.19	0.40	0.07	7.94E+03	6.35E+03	1.41E+03	5.63	0.21	fixed	9.36E+06
M=0.3, steep=0.4*	0.14	0.29	0.83	0.02	1.83E+04	1.28E+04	1.73E+03	6.91	0.08	fixed	3.44E+07
M=0.3, steep=free	0.20	0.29	0.83	0.04	1.35E+04	9.46E+03	1.73E+03	5.22	0.13	0.49	2.72E+07
M=0.3, steep=0.8	0.47	0.29	0.83	0.36	4.02E+03	2.82E+03	9.87E+02	2.13	0.54	fixed	1.00E+07
M=0.4, steep=0.4	0.22	0.41	>2.0	0.07	1.07E+04	6.44E+03	1.33E+03	4.42	0.19	fixed	3.59E+07
M=0.4, steep=free	0.19	0.41	>2.0	0.06	1.18E+04	7.05E+03	1.31E+03	4.67	0.17	0.38	3.87E+07
M=0.4, steep=0.8	0.99	0.41	>2.0	0.99	3.05E+03	1.83E+03	9.93E+02	0.94	0.89	fixed	1.37E+07
Weighted Mean	0.27	0.29	1.01	0.14	1.45E+04	1.06E+04	1.78E+03	6.28	0.22		
Alternative Runs:											
Female SSB	0.28	0.29	0.83	0.18	2.61E+03	1.83E+03	1.04E+03	3.66	0.46	0.30	1.34E+07
Female SSB, steep=0.5	0.52	0.29	0.83	0.52	2.02E+03	1.41E+03	9.86E+02	1.92	0.70	fixed	9.65E+06
w/ MRFSS CPUE	0.21	0.29	0.85	0.04	1.32E+04	9.24E+03	1.74E+03	4.29	0.15	0.50	2.67E+07
Alt. weighting, growth estimated	0.15	0.41	>2.0	0.08	1.33E+04	9.32E+03	1.02E+03	2.06	0.39	0.34	4.01E+07

Other alternative runs were also made as summarized in Table 6.2. These include two runs using mature female biomass only (steepness free and fixed at 0.5). The runs

based on female biomass are more optimistic than those based on total mature biomass, but still suggest that the stock is overfished and overfishing is occurring.

Additional runs with total mature biomass were made, including a run with the MRFSS CPUE in addition to the other CPUE indices, and a run estimating growth parameters using an alternative weighting approach and growth estimated by the model. Results from the run that included the MRFSS CPUE is very similar to the central run that it parallels. The other run with alternative weighting approach and estimated growth is somewhat more optimistic than the central run relative to benchmarks.

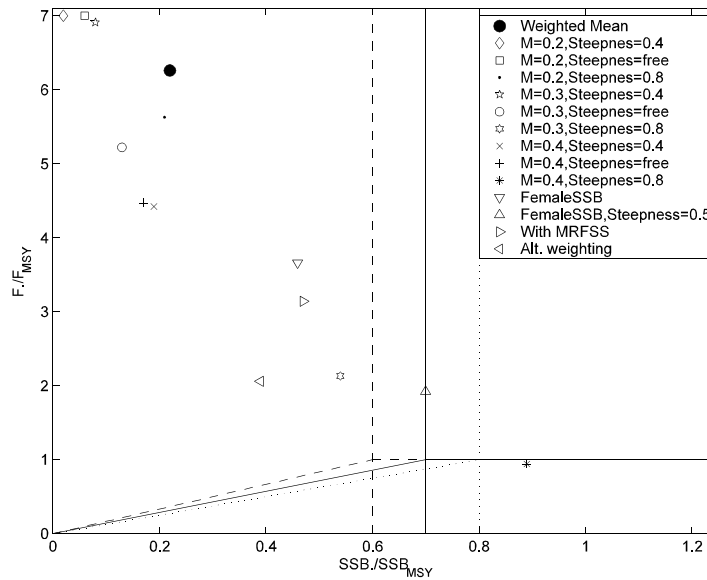


Figure 6.9. Results of the various runs of the stock assessment. F ratios in excess of 7 are set to 7 for graphical purposes. Dotted lines represent MSST and MFMT corresponding to $M=0.2$, solid lines for $M=0.3$, dashed lines for $M=0.4$. Natural mortality $M=0.3$ unless otherwise indicated in the key. Central run is represented by the solid circle.

6.2 Age-aggregated production model

6.2.1 Application of production model

Data used for production modeling were total landings and four abundance indices described in Sections 2, 3 and 4 and Appendix D. Indices of abundance used in this approach included CPUE estimates from headboat and MARMAP hook & line, blackfish and chevron traps. The AW chose as more complete the catch data series that included the reconstructed time-series for the period 1950-1977 (see Appendix D),

continuing on with the data from 1978-2001 as used in the age-structured assessment. Three assumptions were examined relative to the recreational landings compared to commercial landings during the earlier time period (Appendix D).

6.2.2 Results of production model

Unlike some applications of age-aggregated production models, it was not necessary to fix the value of B_1/K to obtain estimates. Fits to the four indices of abundance (3 MARMAP and 1 Headboat CPUE) for base production model run ($R=2C$) are shown in Figure 6.10.

Relative population trajectories (B/B_{MSY}) are most divergent between $R=C$ and $R=2C$, especially during the late 1970s and early 1980s (Figure 6.11). Trajectories of relative fishing mortality rate (F/F_{MSY}) differed even less (Figure 6.11). There is a notable difference in stock status relative to both SSB and F in the 1970s coincident with the shift in assessment data series (1950-1977 and 1978-2001). However, the status at the end of the time series (2001) is similar among the three sensitivity runs.

Estimates of management quantities from the production model describe the stock in 2002 as overfished (B/B_{MSY}) and undergoing overfishing in 2001 (F/F_{MSY}) (Table 6.3). Confidence intervals, derived from bootstrapping, tend to underestimate the uncertainty in the analyses, as is true of most confidence intervals reported for fisheries model estimates. This is for many of the reasons discussed above for the age-structured model.

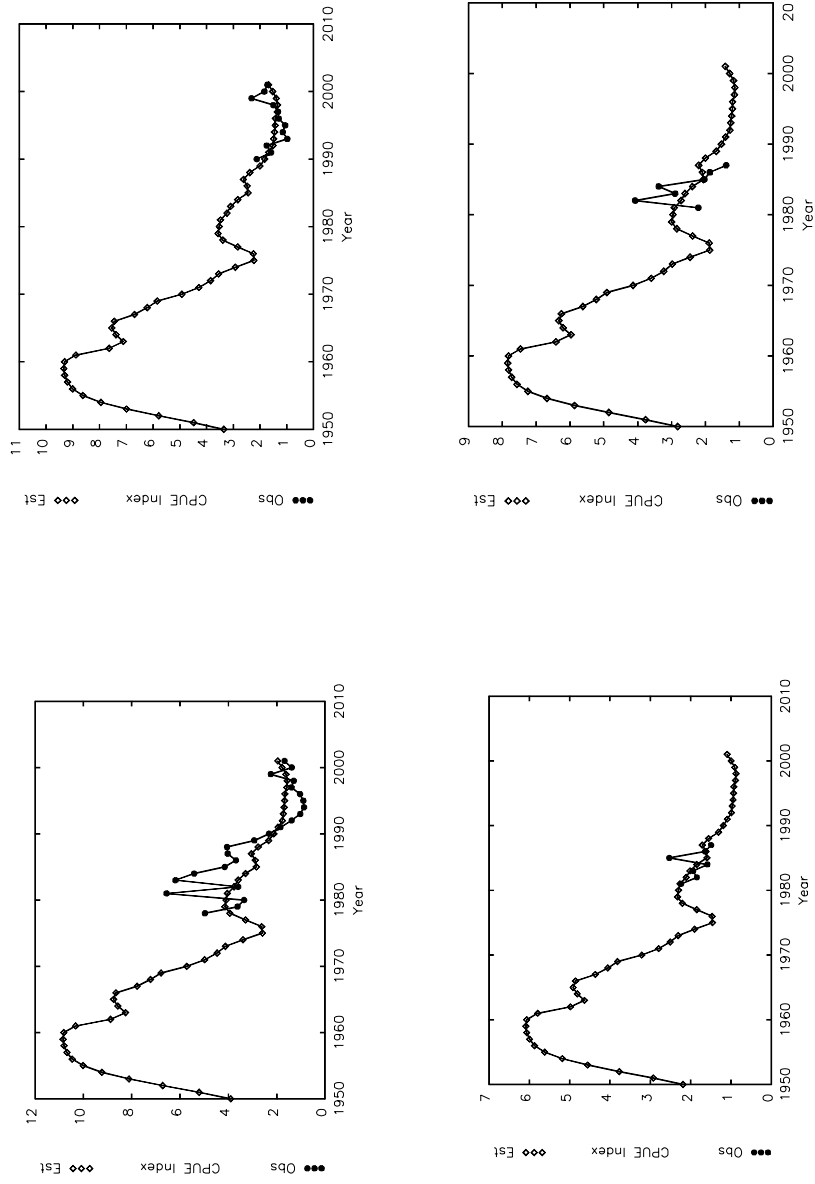


Figure 6.10. Fit of base production model ($R=2C$) against Headboat (upper left) and MARMAP (chevron trap, upper right; blackfish trap, lower left; hook & line, lower right) CPUE.

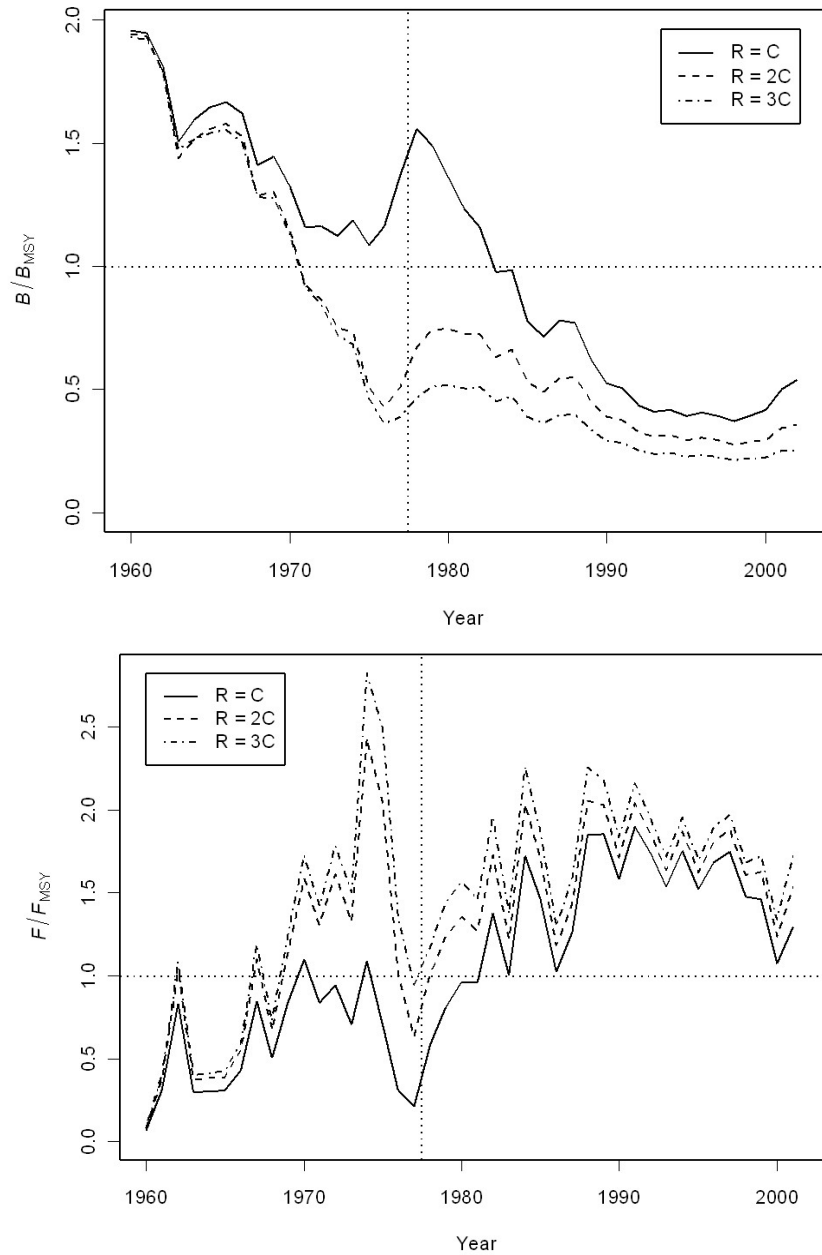


Figure 6.11. Trajectories of B/B_{MSY} and F/F_{MSY} from production model of black seabass. Three trajectories are shown, representing estimates conditioned on different assumptions about the volume of catch prior to 1978. $R=C$ represents the assumption that pre-1978 recreational catch was the same volume as recorded commercial catch; $R=2C$ represents the assumption that pre-1978 recreational catch was twice the recorded commercial catch; and $R=3C$ represents the assumption that pre-1978 recreational catch was 3 times the recorded commercial catch.

Table 6.3. Summary of estimated benchmarks and stock status from application of the production model to black seabass off the southeastern U.S. for 3 levels of recreational harvest relative to commercial harvest during 1950-1977. Bootstrapped 80% confidence intervals presented for base case ($R = 2C$). Note that Y_e is equilibrium yield available in 2002.

Benchmark or status indicator:	$R = C$	$R = 2C$	$R = 3C$
MSY (mt)	1070	1344 (1335, 1351)	1658
B_{2002}/B_{MSY}	0.54	0.36 (0.25, 0.48)	0.25
F_{2001}/F_{MSY}	1.30	1.53 (1.19, 2.01)	1.73
Y_e (mt)	841	791 (602, 988)	728
Y_{e2002}/MSY	0.79	0.59 (0.44, 0.73)	0.44

6.3 Comparison of models

Estimated trends of stock status and fishery status from the two models are qualitatively similar (Figure 6.12). It is important to note that total stock biomass, not SSB, is estimated in the production model. For direct comparison (Figure 6.12), B/B_{MSY} was calculated for the age-structured model. The trends in relative biomass (B/B_{MSY}) are similar between the two model approaches, although the production model is more optimistic relative to the degree that the stock is overfished over the comparable time period, including 2002. The trend in F/F_{MSY} differ importantly during the 1990s where the age-structured model suggests a large increase in F during the late 1990s followed by a decline in the most recent years. This pattern is not captured by the production model. The age-structured model estimates are fully-selected F in numbers, while the production model estimates are average F of the exploited fraction, in weight.

Because the age-structured model incorporates far more information on the stock's biology and on the characteristics of the fishery, the AW considers the BSB2003 age-structured model the more reliable assessment tool. As such, its estimates are considered more likely to be accurate, and the production models and sensitivity runs are considered to give less definitive views of the population. Nonetheless, both models give the same basic picture of the stock's status in 2001 (Tables 6.2 and 6.3): the stock was

overfished, being reduced to about 22% of SSB_{MSY} for the age-structured models (weighted mean of values) versus 36% for the base production model, and it was undergoing overfishing, as F_{2001} was about 630% of F_{MSY} for the age-structured models and about 153% for the base production model.

Given the different assumptions used by each type of model and the lack of age structure in the production models, the similarity of trends in both models and relative stock status increases the AW's confidence that the stock is overfished and overfishing is occurring.

6.4 Comparison to previous assessments

Results from this assessment are qualitatively consistent with results from earlier black seabass stock assessments (Vaughan et al. 1995, 1996). Both of these earlier assessments are based on tuned VPA (FADAPT). The first assessment, which included data through 1990 (Vaughan et al. 1995), suggested that fishing mortality during the 1980s was slightly above the $F_{30\%}$ SPR target/threshold. However, the second assessment, with data through 1995 (Vaughan et al. 1996), suggested that a somewhat greater level of overfishing might be occurring in the early 1990s relative to the $F_{30\%}$ SPR target/threshold. Levels of static SPR estimated in the first two assessments were generally in the 20-30% range for 1979-1995. This assessment estimates static SPR at slightly higher values, on the order of 25-35% (Figure 6.13). The current assessment suggests that the level of fishing mortality that is appropriate as a threshold ($F_{MSY} = 0.27$ in Table 6.2) is considerably lower than $F_{30\%}$ (0.7 in Table 10 from Vaughan et al. 1996). Our estimate of F_{MSY} is equivalent to static SPR of about 55%. This suggests that the static SPR proxy of 30% may not adequately protect the stock (see Section 7.1).

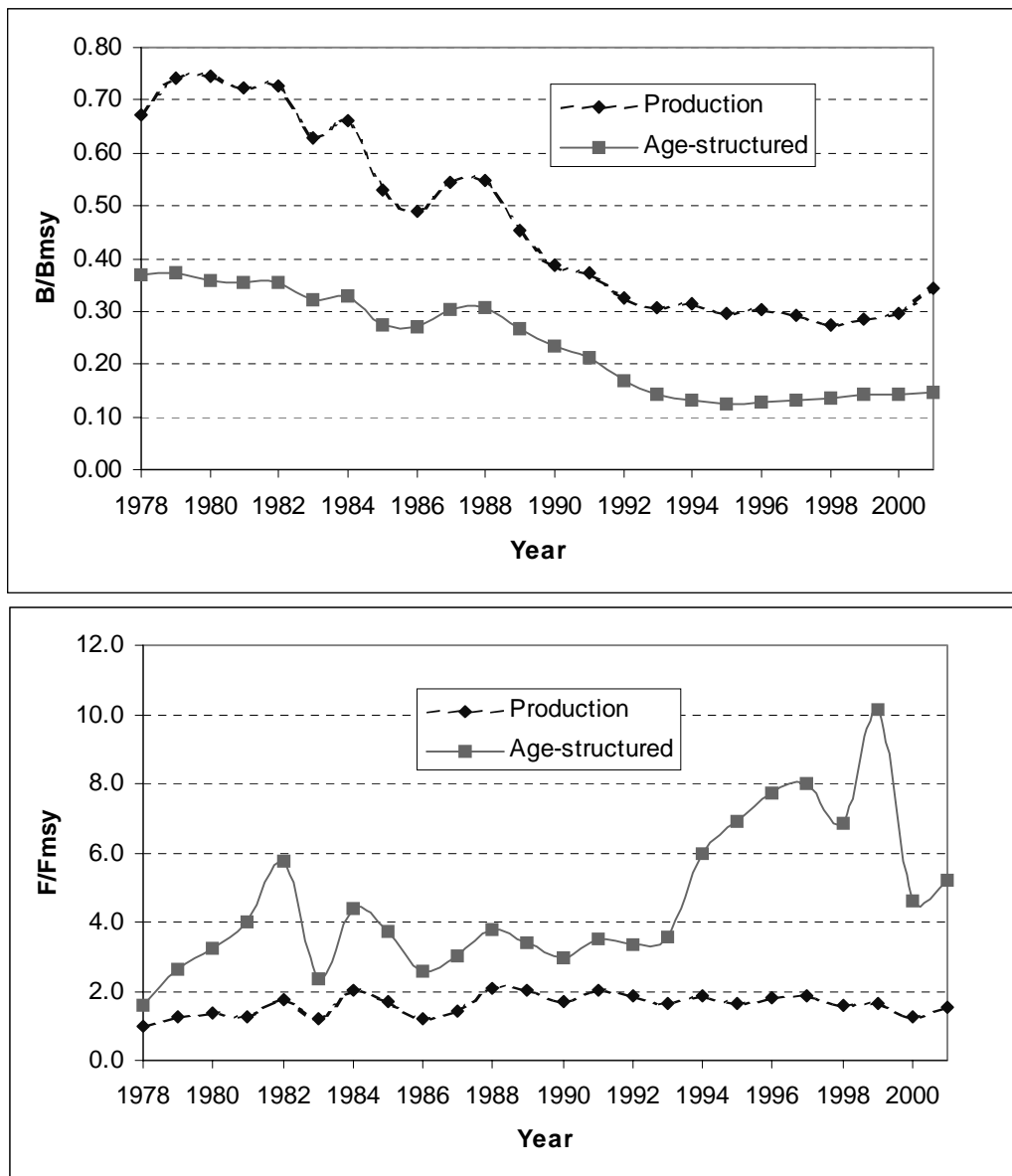


Figure 6.12. Comparison of estimated stock and fishery status from the central run ($M=0.3$, $h=free$) of the age-structured model and the base run ($R=2C$) of the production model.

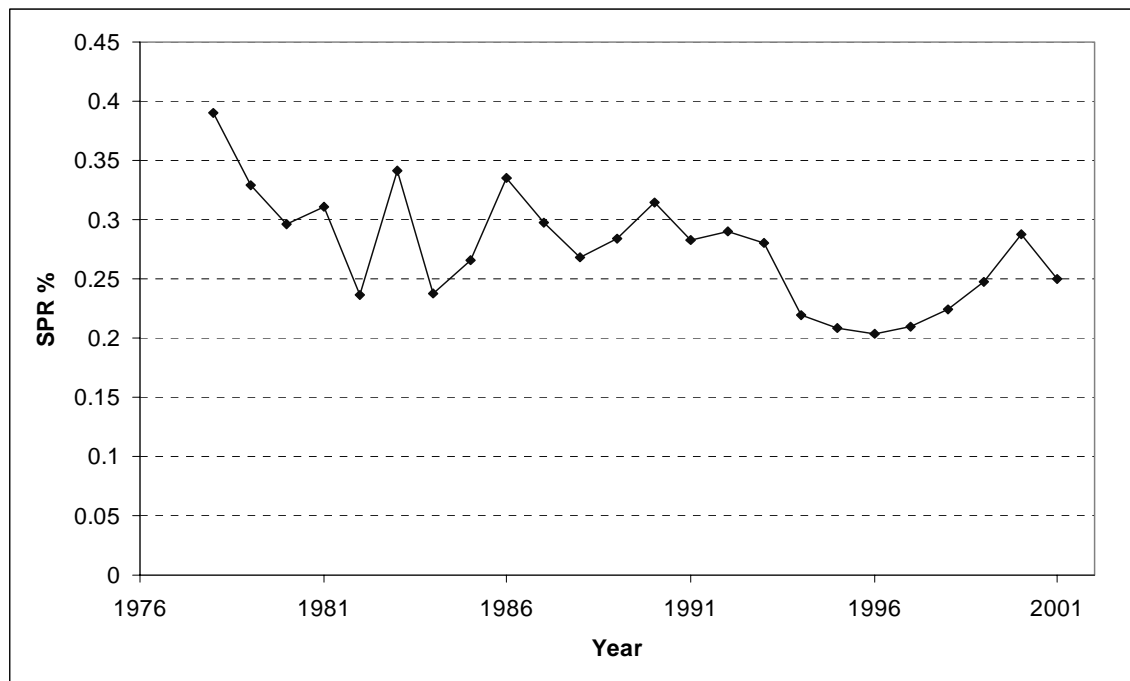


Figure 6.13. Annual estimates of static spawning potential ratio (%SPR) for the central run of BSB2003.

7 Biological reference points

7.1 Proxies and estimated reference points

Concern by the AW of uncertainty in the model fits, the assumption of natural mortality (M), and difficulty in estimating steepness (h), led to a recommendation to base the scientific advice on the weighted average of estimates of F_{MSY} , SSB_{MSY} , and related quantities. Weighting is given in the matrix of M and h combinations from Table 6.1. This assessment provides direct estimates of the required management benchmarks which should be used instead of current proxies. For determining status of the stock, the AW recommends consideration of the weighted average of the status indicators F_{2001}/F_{MSY} and $SSB_{2002}/SSB_{\text{MSY}}$.

Proxies for management benchmarks are typically developed from SPR and YPR plots as shown here for the central run (Figure 7.1). Static SPR proxies are based on levels of F that will provide a certain level of spawning biomass relative to the maximum level at $F=0$. YPR proxies are based on maximizing yield and do not provide protection of the spawning stock. Typical proxies from YPR include F_{max} and $F_{0.1}$. The latter proxy has been used in Canada and Europe, and was developed to be somewhat more conservative than F_{max} . As shown in Figure 7.1, F_{MSY} (0.2) is somewhat lower than $F_{0.1}$ (0.3), and considerably lower than F_{max} (0.8). All of these values are below the estimated F in the terminal year (1.1).

The existing proxies, which are based on spawning potential ratio (SPR), have not proven sufficiently restrictive to maintain the stock (Vaughan et al. 1996, and this report). Even though prior assessments and this assessment have estimated SPR values similar to the proxy threshold/target over the assessment period, the SSB has declined (Figure 6.6). No firm theoretical basis is known for deriving an SPR value to maintain high sustainable yields without having detailed knowledge of the species' population characteristics, knowledge that is often sufficient to compute actual benchmarks. Several levels of SPR have been recommended in the fisheries literature as general cases, and those levels have tended to increase as empirical experience has accumulated. For example, Goodyear (1993) recommended 20% to 30% as "critical levels," Clark (1993) recommended 40% (an increase from his earlier recommendation of 35%), and Mace (1994) recommended using 40% SPR as a default in many conditions. Clark (2002) found that "at low ...levels of resiliency, the $F_{40\%}$ strategy results in undesirably low levels of biomass and recruitment by present-day standards." Based on this assessment, even these levels above do not appear to be sufficiently restrictive, and that a threshold level of static SPR for black seabass may be above 50% (Figure 7.1). Although SPR proxies can be useful approximations when management quantities cannot be estimated, the use of SPR proxies for black seabass is now unnecessary, and use of estimated benchmarks has a firmer biological basis.

7.2 Protogyny and reference points

The protogynous nature of black seabass creates complications in management not encountered with gonochoristic species (non-sex switcher). Protogynous species may switch from female to male as they age. Selective removal of fish by size, either smaller females or larger males, will affect the reproductive potential of the population in ways we do not fully understand. SSB in this assessment combines mature males and females and therefore assumes both sexes have equal contributions to production of recruits.

Examination of SSB by sex indicates a long-term decline in male SSB coupled with a sudden decline in female SSB in the early 1990s (based on central run in Figure 7.2). The decline in male SSB is reflective of sustained high mortality rates truncating the age structure over time. The decline in females may have been triggered by a shift in selectivity by the commercial gear and was likely exacerbated by poor recruitment. Estimated selectivity for the primary commercial gears (traps and lines) shifted toward younger fish during the period when an 8" TL minimum size was imposed, which is contrary to the intended effect of a size limit and could be a result of market demand or availability. The lowest recruitment values of the series are observed within a few years after female SSB begins to drop; the lack of recruitment into the population drives SSB down even further. Both male and female SSB stabilize by 1995, although lower and apparently less productive in terms of recruitment.

The female spawning biomass was reduced at a slower rate particularly after imposition of minimum size limits. In such a situation, a target fishing mortality with large minimum sizes in the fishery is likely to result in differential mortality between the sexes. Consequently, the target fishing mortality may achieve the target SSB while the corresponding sex ratio of the population may not be optimal for sustaining yield. For that reason, Vaughan et al. (1992) recommended use of total mature biomass, rather than female mature biomass, in estimation of reference points based on spawning biomass. The effect of fishing on the transition rate from female to male has not been well studied. In devising management measures to rebuild the spawning stock, the size and sex structure of the target SSB should be considered as well as its total biomass.

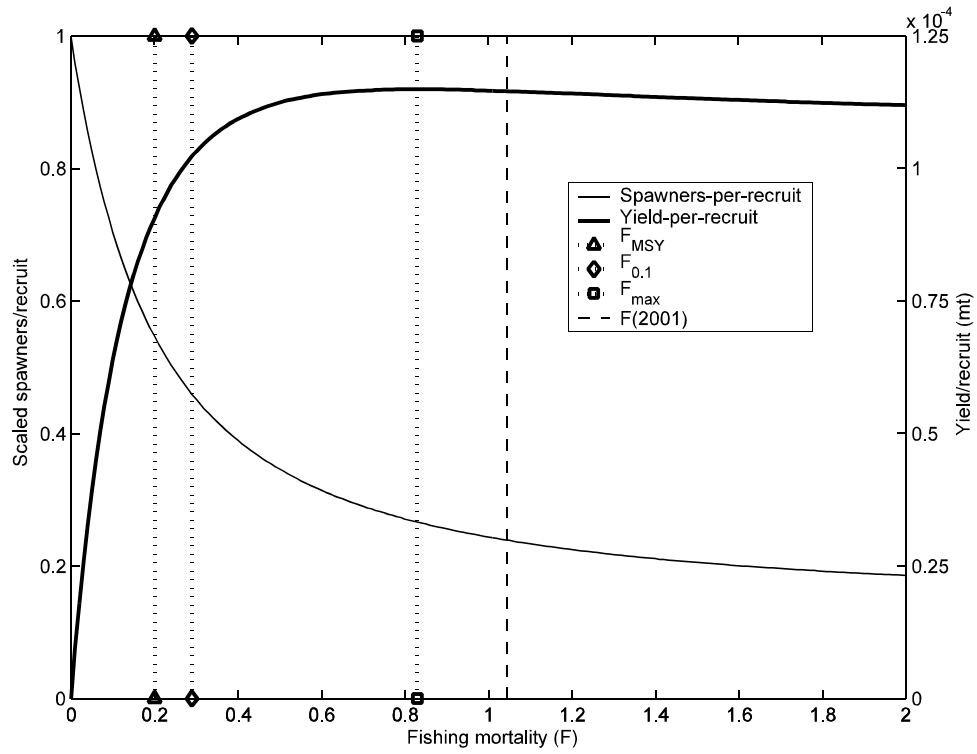


Figure 7.1. Static SPR and YPR based on the central run with selectivity for 1999-2001. Vertical lines represent various benchmark mortality levels, including F_{MSY} , $F_{0.1}$, F_{max} and F_{now} .

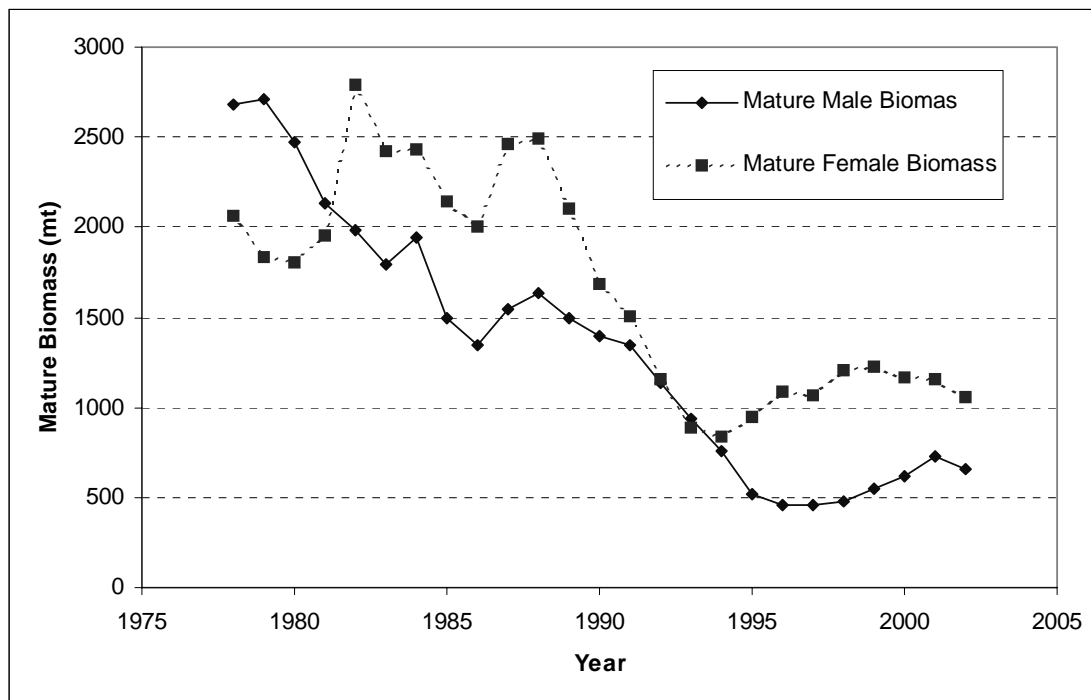


Figure 7.2. Mature SSB by sex from the central run of BSB2003.

8 Stock projections

8.1 Age-structured projections

To evaluate the likely odds of recovery under a range of possible future management measures, simulations were used to project the stock forward for each of the sensitivity runs (Table 6.1). The mean of the sensitivity runs was developed based on the weighting probabilities for combinations of M and h as assigned by the AW for status of stock.

8.1.1 Structure of simulations

The age-structured model was used to project the population forward 25 years under several different management regimes. Recruitment in each year was generated with the stochastic spawner–recruit model estimated by that particular sensitivity run. The 25–year projection was repeated 2000 times for each of the sensitivity runs and under each management regime.

The rebuilt state for each sensitivity run was defined as a 50% probability that the stock reaches the SSB_{MSY} specific to that run (Table 4). The proportion of realizations that reached or exceeded the rebuilt state in each projection year was used as an estimate of the stock’s probability of attaining the rebuilt state by January 1 of that year under that management regime.

Initial stock size and F Initial (2001) stock sizes at age were as estimated by the various runs used in characterizing the uncertainty in the assessment. Selectivity and geometric mean F for the period 1999–2001 were used to represent current fishing mortality (F_{now}) and provided a basis for determining F that can rebuild the stock in the prescribed time frame.

Life-history parameters Proportions mature at age, sex ratios at age, and release mortality rates were those provided by the Data Workshop for the most recent period.

Stock–recruitment model Population projections used an empirical bootstrap method to implement a stochastic stock–recruitment model. Each sensitivity run provided its own set of parameter estimates for the Beverton–Holt model and a vector of residuals for the model years 1978–2001. Deterministic recruitment values for projections were generated by the fitted stock–recruitment model specific to the pertinent sensitivity run. Stochasticity was implemented by adding residuals chosen at random from the residuals vector to the deterministic recruitment values.

Spawning stock biomass The SSB_{MSY} against which projections are measured is specific to each sensitivity run (Table 6.1).

Generation Time Calculation of generation time is based on Goodyear (1995) as presented in the Technical Guidance document (modified from Restrepo et al. 1998):

$$G = \frac{\sum_{a=1}^A a W_a O_a N_a}{\sum_{a=1}^A W_a O_a N_a}$$

Weight at age (W_a) is used in place of fecundity at age. Numbers at age, adjusted for total mature individuals at age ($O_a N_a$), is based on declining population size (N_a) for a range in natural mortality rate ($M = 0.2, 0.3, 0.4$) as adjusted for total maturity at age (O_a). Maximum age (a) is set at 50 (A) as recommended by the AW. Estimated generation times were 7.0 yrs for $M=0.3$ with range of 5.5 yrs ($M=0.4$) and 9.7 yrs ($M=0.2$). Values were rounded up to whole integer values for determining F that will rebuild SSB to SSB_{MSY} in the rebuilding period in the projections.

8.1.2 Fishing mortality rates for projections

Projections begin with the year 2002, after the final year of model fitting. Projections begin with model year 2002, the terminal year for which the assessment model produces population estimates for January 1 of that year. The stock is projected to the year 2026 for each sensitivity run using three different values of fishing mortality rate. All sensitivity runs were projected using $F = 0$ and the run-specific F_{now} . Sensitivity runs were also projected using $F_{rebuild}$ if benchmark estimates indicated rebuilding is necessary [i.e., $SSB < (1-M)SSB_{MSY}$], as with eight of the nine sensitivity runs. Only the case of $M = 0.4$ and $h = 0.8$ did not require rebuilding, and for this sensitivity run, only two fishing mortality values are projected. For the other eight cases, $F_{rebuild}$ was determined by the following method: 1) Project the stock forward using $F = 0$; 2) if SSB has at least a 50% chance of rebuilding to SSB_{MSY} within 10 yrs, then the allotted rebuilding time is 10 yrs; 3) if the $F = 0$ projection requires more than 10 yrs to rebuild, then the duration required plus one generation time becomes the allotted time frame; and 4) $F_{rebuild}$ is the F that provides a 50% chance of rebuilding to SSB_{MSY} in the allotted time frame (10 or more years).

Any changes in F begin with the projection in 2002. Although management measures can not take effect until 2003 or later, it is the duration of the rebuilding period that is being estimated, rather than the specific start and stop years. Rebuilding projections will be optimistic if there is further decline in the population prior to the imposition of additional management.

8.1.3 Projection results

Separate projections were made for each element of the matrix and for the various values of F . Table 8.1 summarizes those results. Summaries of the SSB projections for current F , $F=0$, and rebuilding F are presented for the central run and other sensitivity runs (Table 8.1). Note that the sensitivity run for $M = 0.4$ and $h = 0.8$ was unique in that it did not depict a stock that required rebuilding, and consequently there is no corresponding rebuilding F projections.

Table 8.1. Summary of age-structured projections for black seabass.

Sensitivity Runs	Current F (F_{now} *)	No. years to rebuild with $F=0$ **	No. years allotted for rebuilding ***	F that rebuilds in allotted time (F_{rebuild})	$F_{\text{rebuild}}/F_{\text{now}}$
M=0.2, steep=0.4	1.36	15	25	0.18	0.13
M=0.2, steep=free	1.75	11	21	0.21	0.12
M=0.2, steep=0.8	1.56	6	10	0.20	0.13
M=0.3, steep=0.4	0.99	15	22	0.10	0.10
M=0.3, steep=free	1.13	11	18	0.16	0.14
M=0.3, steep=0.8	1.13	2	10	0.49	0.43
M=0.4, steep=0.4	1.10	11	17	0.15	0.14
M=0.4, steep=free	1.00	12	18	0.13	0.13
M=0.4, steep=0.8	1.08	NA	NA	NA	NA
* F_{now} = geometric mean of $F(1999)$, $F(2000)$, $F(2001)$ ** Rebuild to SSB_{MSY} *** Must rebuild in ten years if possible, otherwise one generation plus no. years with $F=0$ (Generation times: 10 yrs for $M=0.2$, 7 yrs for $M=0.3$, 6 yrs for $M=0.4$)					

Projections of SSB from the central run are shown in Figure 8.1 (additional sensitivity runs can be found in Appendix E). The summary across the nine separate projection runs based on weighting in Table 6.1 is shown in Figure 8.2. For $F=F_{\text{now}}$ the SSB remains low relative to SSB_{MSY} . Timing of rebuilding is variable, depending on the sensitivity run and level of F ($F=0$ or $F=F_{\text{rebuild}}$).

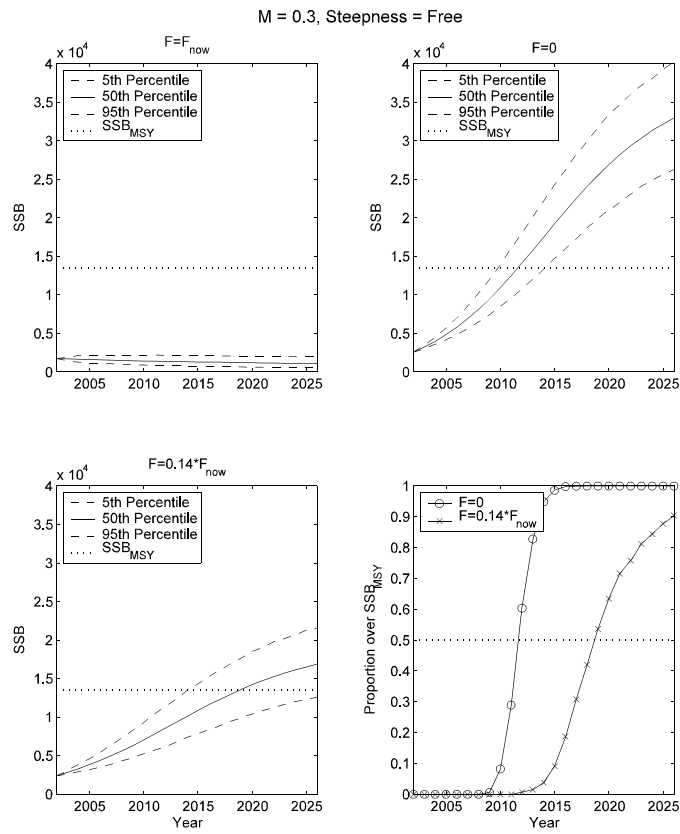


Figure 8.1. SSB projections for the central run ($M = 0.3$, steepness = free). $F_{rebuild}$ is $F = 0.14 * F_{now}$.

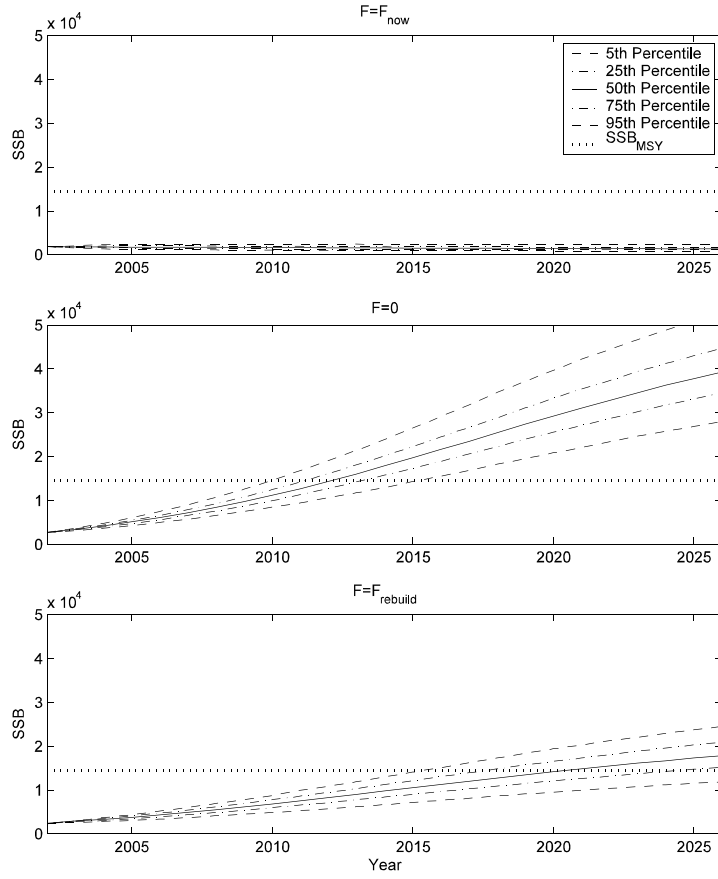


Figure 8.2. Weight Mean of SSB projections for F_{now} , $F=0$, and F_{rebuild} . Note that panel C excluded the case of $M = 0.4$ and steepness = 0.8 because it required no rebuilding; weightings of the remaining eight cases were rescaled to sum to one.

According to the projections, SSB will remain low and may decline further if fishing mortality is not reduced. The low stock abundance and continued poor recruitment will constrain yields in spite of high levels of F . If fishing mortality is initially reduced to the rebuilding level, yields will initially be low, but within a few years, yields will exceed current yields based on both the central run (Figure 8.3) and the weighted representation (Figure 8.4).

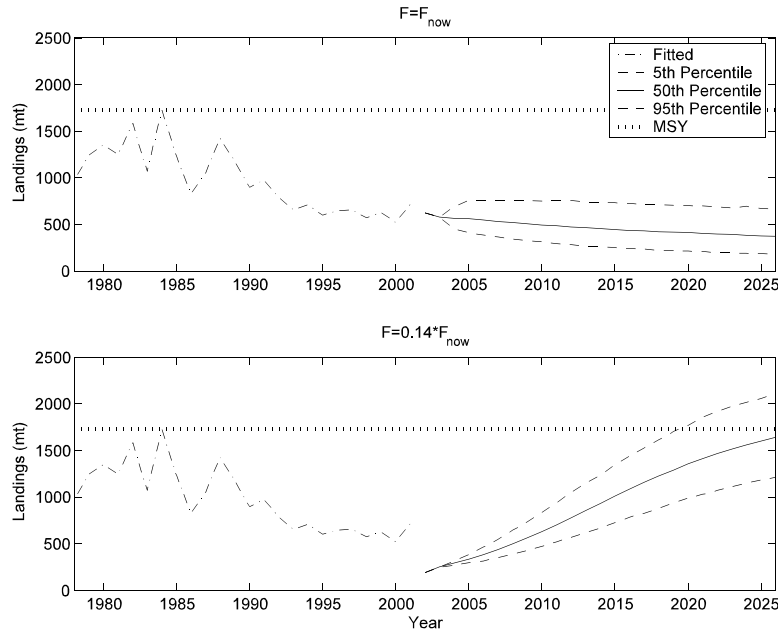


Figure 8.3. Yield projections for the central run ($M = 0.3$, steepness = free). $F_{rebuild}$ is $F=0.14*F_{now}$. Historical predicted yields from the assessment are shown for 1978-2001.

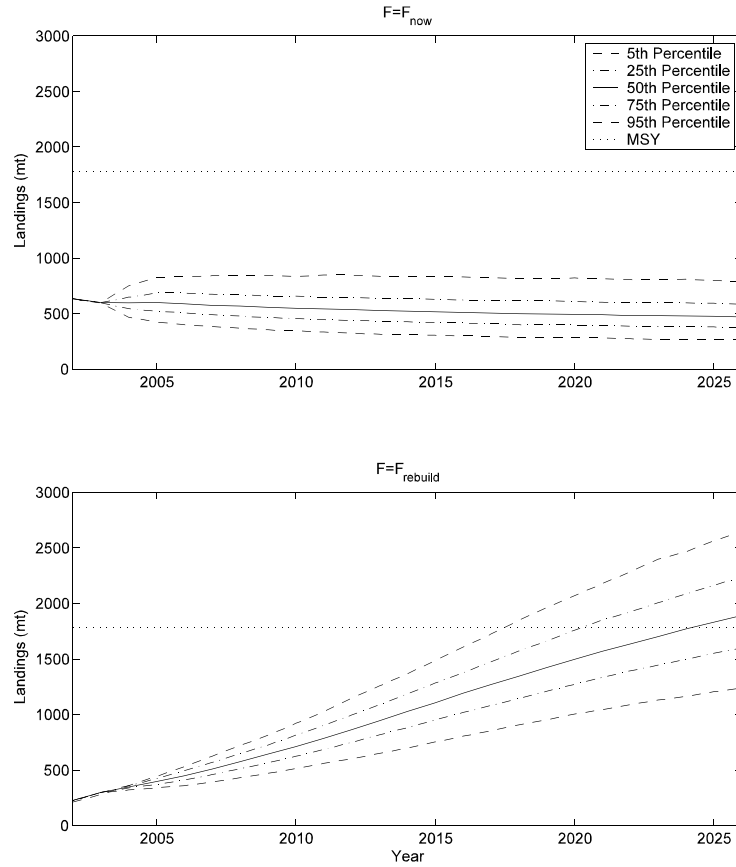


Figure 8.4. Weighted mean landings across all sensitivity projections. Note that second panel excluded the case of $M = 0.4$ and steepness = 0.8 because it required no rebuilding; weightings of the remaining eight cases were rescaled to sum to one.

The central run suggests that an 86% decrease in fishing mortality from current levels is necessary to rebuild the stock in 18 years (Table 8.1). Although this appears to be drastic, it is only because the current level of F is estimated to be high (1.13), and not that the rebuilding F is exceedingly low (0.16). Long-term threshold for F for the central run is 0.2, somewhat higher than the rebuilding F .

8.2 Age-aggregated production model

Projections were made from the base production model run ($R=2C$) for three levels of F : $F=0$, $F=60\%$ of F_{now} , and $F=100\%$ of F_{now} . Projections of B/B_{MSY} are shown in Figure 8.5. For $F=0$, recovery is rapid, and for $F=100\%$ of F_{now} recovery does not occur within the projection time frame. However, recovery within 10 years occurs for $F=60\%$ of F_{now} .

A comparison of projected yields at $F=60\%$ of F_{now} and $F=100\%$ of F_{now} is shown in Figure 8.6. Yield from 60% of F_{now} quickly exceeds that of 100% of F_{now} (after 4 yrs). This comparison between F_{now} and 60% of F_{now} show that considerable gains in yield could be obtained within 4 yrs if fishing mortality is reduced by 40%.

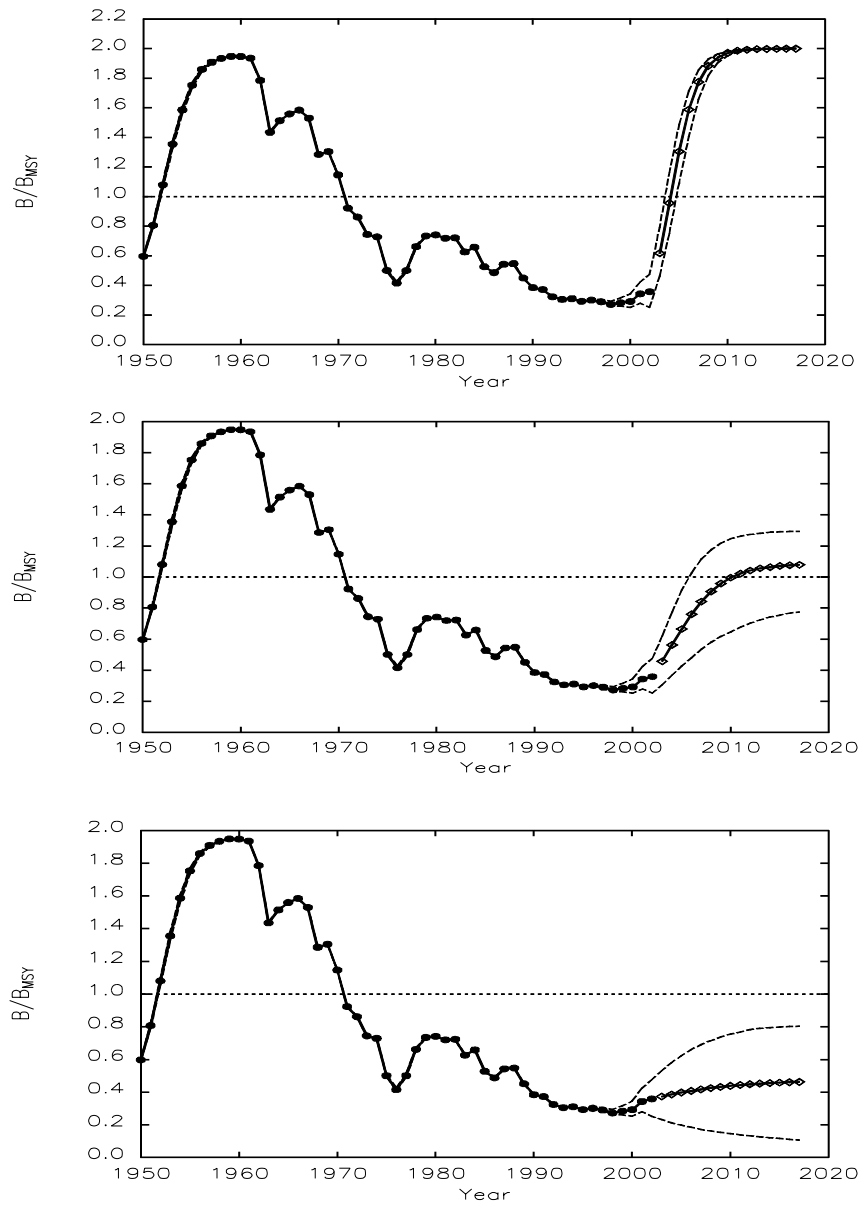


Figure 8.5. Relative population biomass projected for three levels of F : $F = 0$; $F = 0.6$ F_{now} ; and $F = F_{now}$.

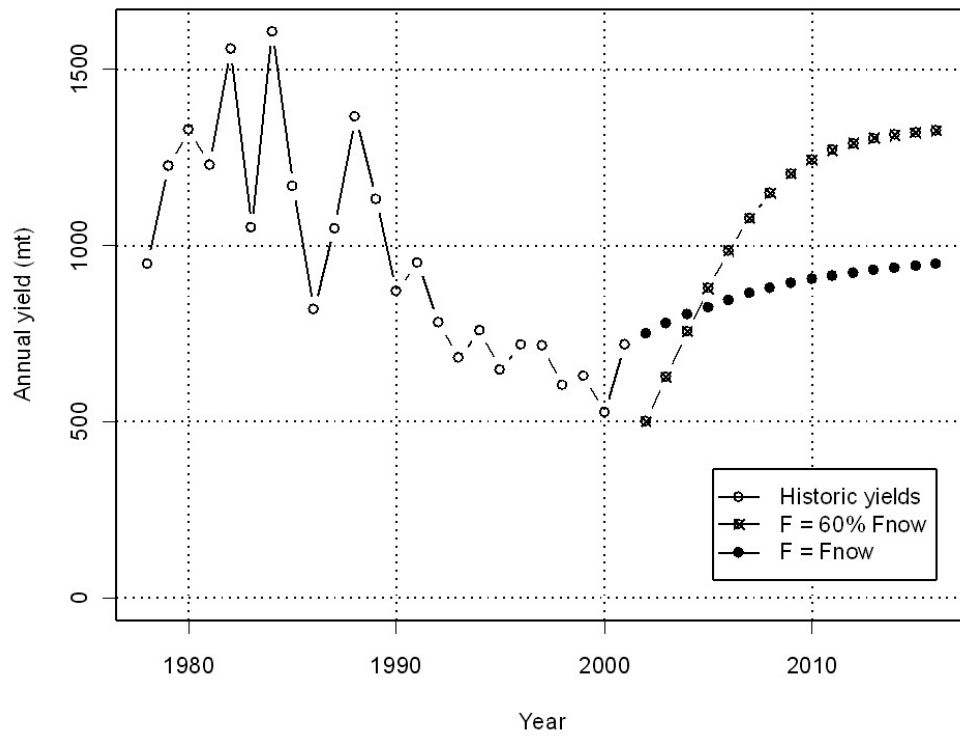


Figure 8.6. Projection of yield with current F and 60% of current F .

9 Research recommendations

The AW discussed aspects of the biology, sampling, and assessment of this population that make accurate and precise assessment more difficult. Execution of the following recommendations for research and data management could improve future assessments of black seabass.

1. Representative age sampling is needed (proportional); also commercial age sampling.
2. Increases in fishery independent sampling.
3. Development of logbook indices is recommended.
4. Information about fecundity is needed (batch fecundity and frequency at age and/or size).
5. Further consideration of implications of change in sex for fishery management.
6. Further development of analytical models to incorporate historical catch information.

Future research should be conducted to further develop age-structured models that could account for historic landings. Specifically, methods that allow scaling of uncertainty in landings records over time are needed. We need to include more historical records which are more uncertain than current records, this may be done by changing CVs over time as opposed to constant CV for a data series.

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APPENDICES

Appendix A. Abbreviations and symbols

Symbol	Meaning
ADAPT	A type of tuned VPA often used in assessment of North Atlantic fish stocks
AW	Assessment Workshop for black seabass
B	Total biomass of stock
B_{MSY}	Total stock biomass at which MSY can be attained (in production models)
BSB2003	The forward-projecting age-structured assessment model used here; see §5.1
CPUE	Catch per unit effort; used after adjustment as an index of abundance
DW	Data Workshop for black seabass
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
K	Average size of stock when not exploited by man; carrying capacity
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery independent data collection program of SC DNR
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often set to F_{MSY}
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS
MSST	Minimum stock-size threshold; a limit reference point used in US fishery management. The SAFMC has defined MSST for black seabass as $(1 - M)B_{\text{MSY}} = 0.7B_{\text{MSY}}$.
MSY	Maximum sustainable yield
mt	Metric tons(s)
NC	State of North Carolina
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
R	Recruitment
SAFMC	South Atlantic Fishery Management Council
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SFA	Sustainable Fisheries Act
SSB	Spawning-stock biomass
SSB_{MSY}	Spawning-stock biomass at which MSY can be attained (in age-structured models)
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length)
VPA	Virtual population analysis, an age-structured assessment model characterized by cohort-wise computations backward in time; “tuned” VPA also employs abundance indices to influence the estimates
yr	Year(s)

Appendix B. Terms of reference for Assessment Workshop

The Assessment Workshop's task is to produce a stock assessment for the Black Seabass and Vermilion Snapper stocks in the SAFMC's area of jurisdiction. This work is done with reference to the U.S. Sustainable Fisheries Act and its National Standards, which govern the Council's management. A written final report (using word or wordperfect software), providing an overview of the analyses, general findings, and recommendations of the workshop, will be available by conclusion of the workshop. A detailed technical addendum on the models used will be available and distributed on or before January 27, 2003.

1. Identify modeling approaches appropriate to the available data and management questions (e.g., production models, age-structured models, hybrids). The Data Workshop recommended the Forward Projection Model approach.
2. Determine all SFA-required benchmarks (MSY, BMSY, MSST, MFMT, and FMSY). Other standard benchmarks should also be provided (e.g., F0.1, Fmax, etc).
3. Estimate stock status (biomass) and fishery status (fishing mortality rate) relative to appropriate SFA benchmarks. Is the stock overfished; is overfishing occurring?
4. If the stock(s) are overfished, identify and conduct rebuilding analyses (projections of rebuilding to MSST and BMSY; yield streams over the rebuilding time-frame). The rebuilding analyses should include: (a) F=0, (b) F=current management measures, and (c) other possible scenarios.
5. Provide recommendations for future research (field and assessment) and data collection necessary to improve assessment results.

Additional specific questions from the Council may be developed and if so, it will be presented to the Assessment Workshop at its meeting.

Appendix C. Workshop attendees

Dagger (†) denotes attendance at Data Workshop only; asterisk () denotes attendance at Assessment Workshop only; others attended both workshops.*

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Appendix D. Historical black seabass landings prior to assessment (1950-1977).

To develop perspective for the status of stock at the start of the assessment period (1978-2001), relevant data sets prior to the assessment (1950-1977) were explored during the AW. These data were not used explicitly in the age-structured modeling. However, these data, with the assumptions given below, were used to extend the time frame for application of the production modeling approach.

Commercial landings of black seabass made from the U.S. south Atlantic were obtained prior to the time-series used in the assessment (Figure D.1). Additionally, recreational landings were found to have been considerable during the pre-assessment period. The 1960, 1965 and 1970 Saltwater Angling Surveys (Clark 1962, Deuel and Clark 1968, Deuel 1993) indicated recreational landings of about 295 mt, 770 mt, and 5600 mt of black seabass, respectively, by anglers from the South Atlantic Region (Cape Hatteras to Florida). These estimates are higher than the commercial landings documented from the region for those years. During the assessment period, the ratio of recreational landings to commercial landings of black seabass from the region ranged from 1-3 (Figure 2.2). To evaluate potential effects of pre-assessment period landings on the assessment, total annual landings prior to 1978 were estimated by assuming recreational landings ranged from being equal to commercial to 3 times the commercial values (Figure D.2).

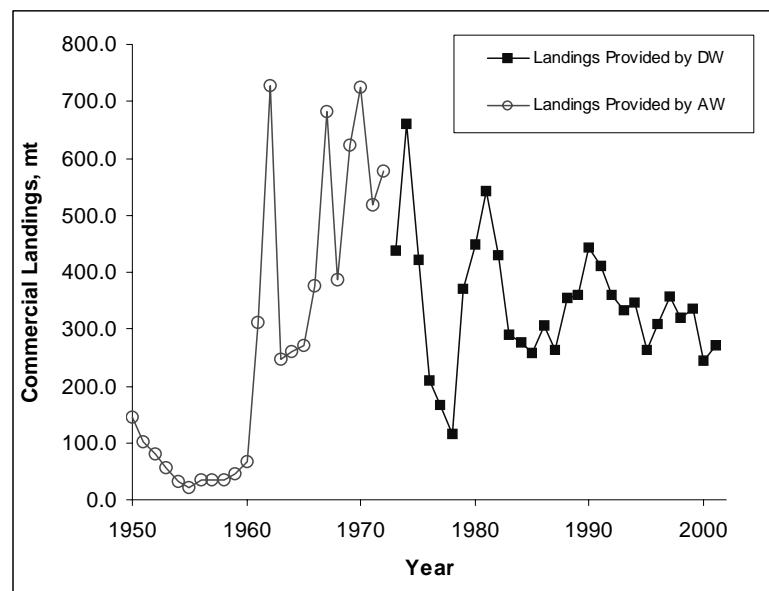


Figure D.1. Commercial landings of black seabass from the southeastern US Atlantic management unit. Closed squares represent the commercial landings information provided by the DW (1973-2001). Open circles represent commercial landings development from the NMFS website during the AW (1950-1972).

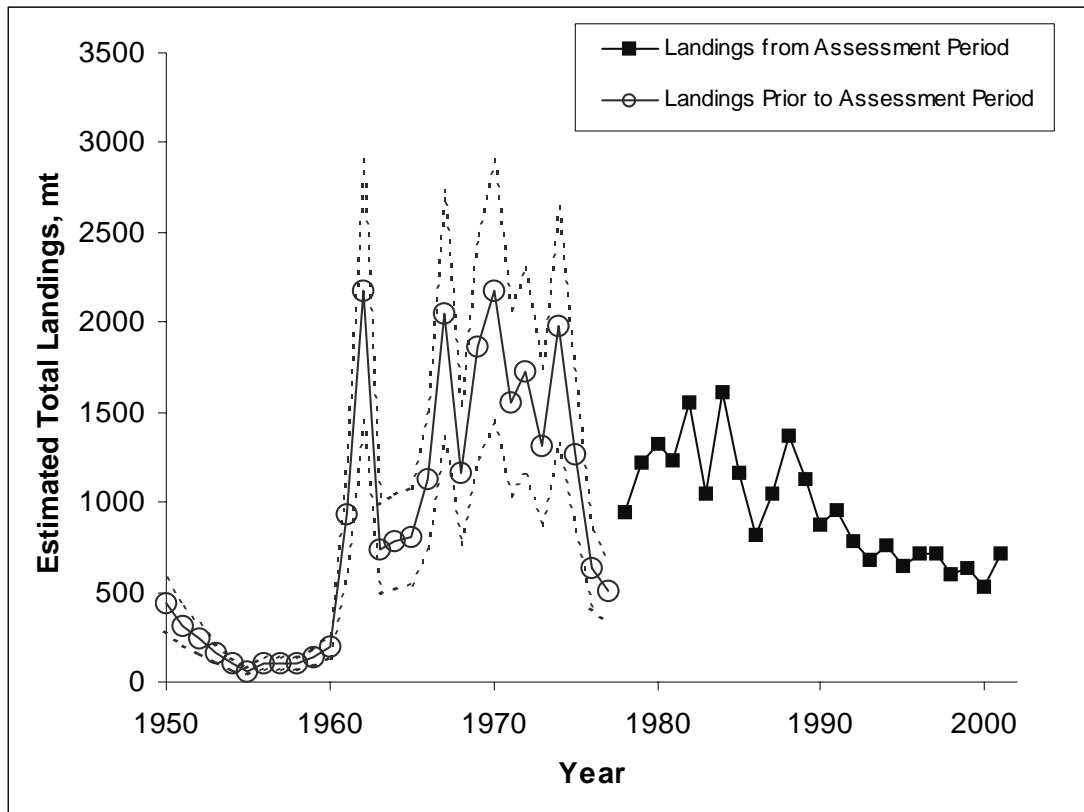


Figure D.2. Estimated total landings of black seabass assuming that recreational landings were twice, on average, the commercial landings in the period prior to the time series used in the assessment (open circles). Also shown are estimated pre-assessment total landings assuming that recreational landings were equal to commercial landings in the pre-assessment period and estimated total landings assuming recreational landings were 3 times the commercial landings in the pre-assessment period (upper and lower dashed lines).

Appendix E. Results from the matrix of sensitivity runs other than the central run.

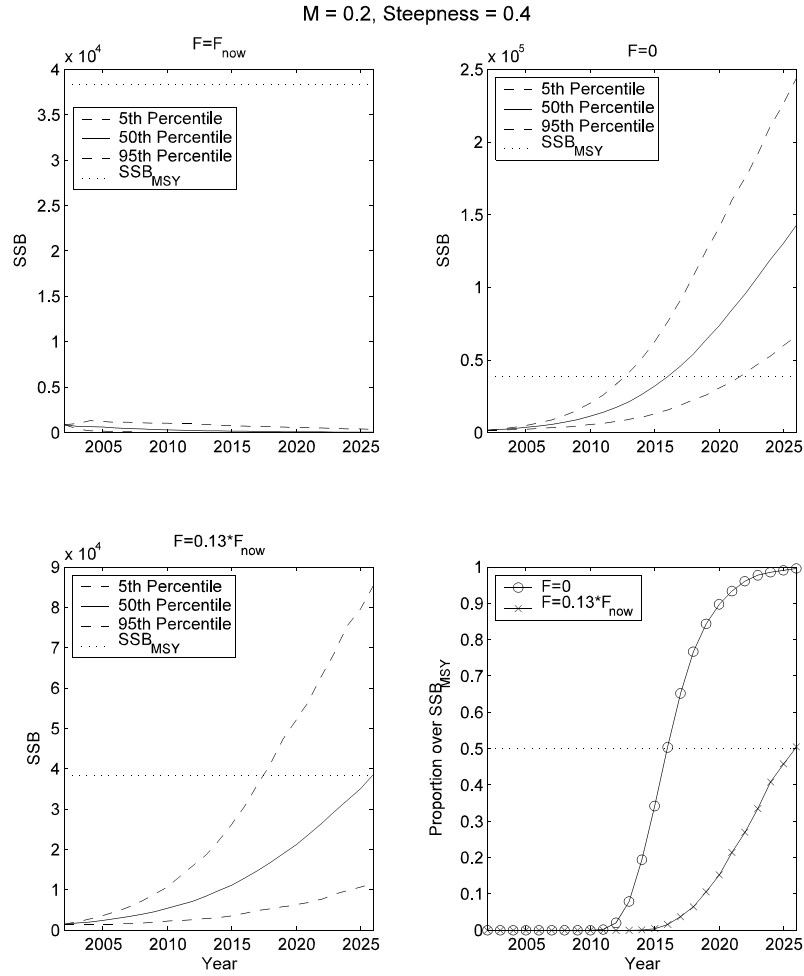


Figure E.1. SSB projections for $M=0.2$, steepness = 0.4. F_{rebuild} is $F=0.13 \cdot F_{\text{now}}$.

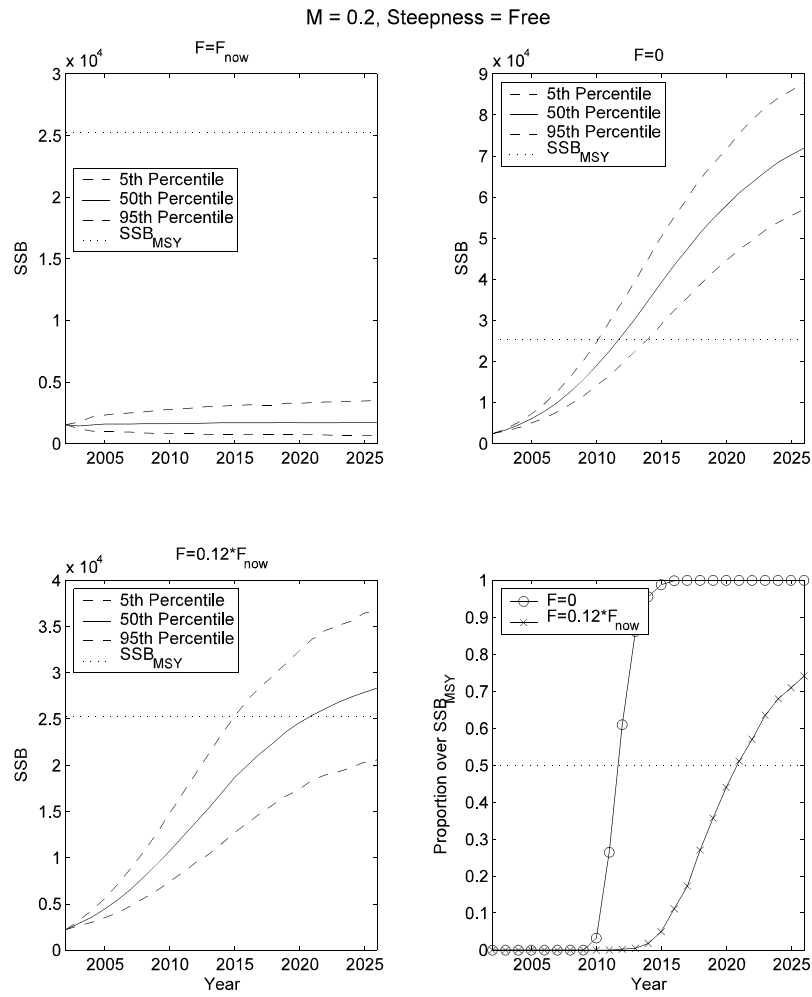


Figure E.2. SSB projections for $M = 0.2$, steepness = free. F_{rebuild} is $F = 0.12 * F_{\text{now}}$.

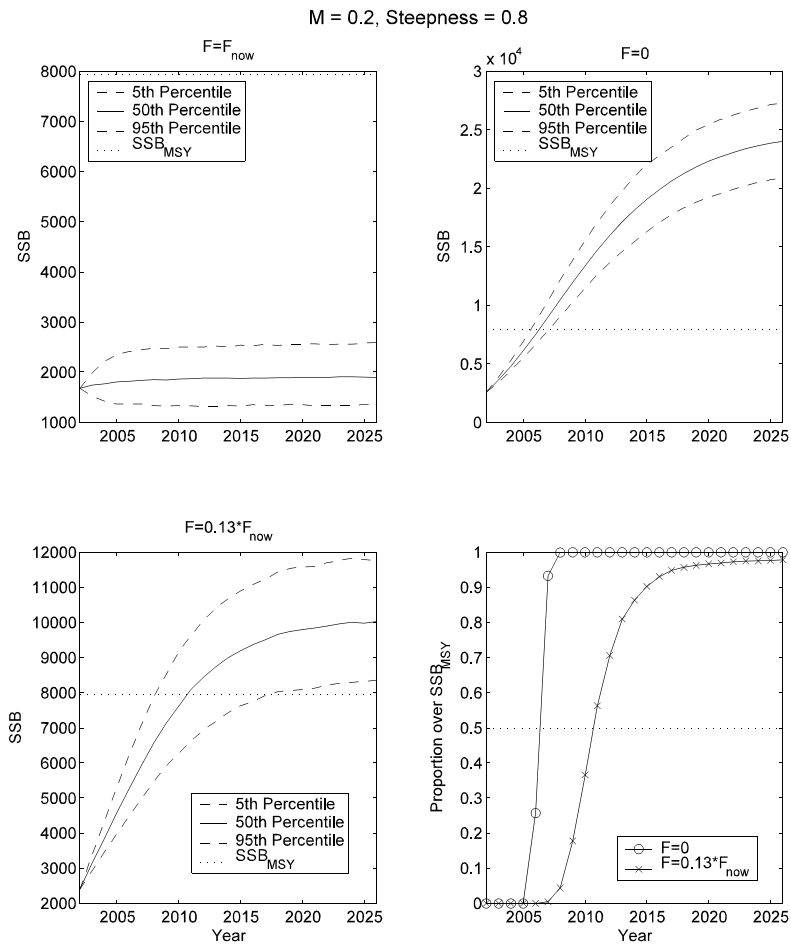


Figure E.3. SSB projections for $M = 0.2$, steepness = 0.8. F_{rebuild} is $F = 0.13 * F_{\text{now}}$.

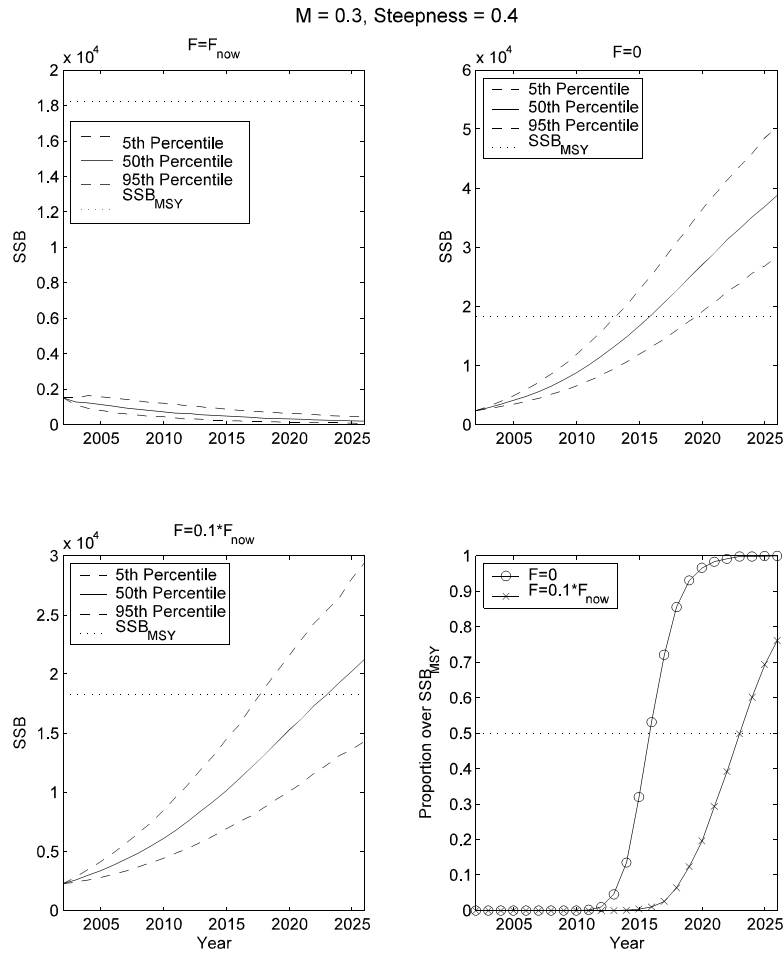


Figure E.4. SSB projections for $M = 0.3$, steepness = 0.4. F_{rebuild} is $F = 0.1 * F_{\text{now}}$.

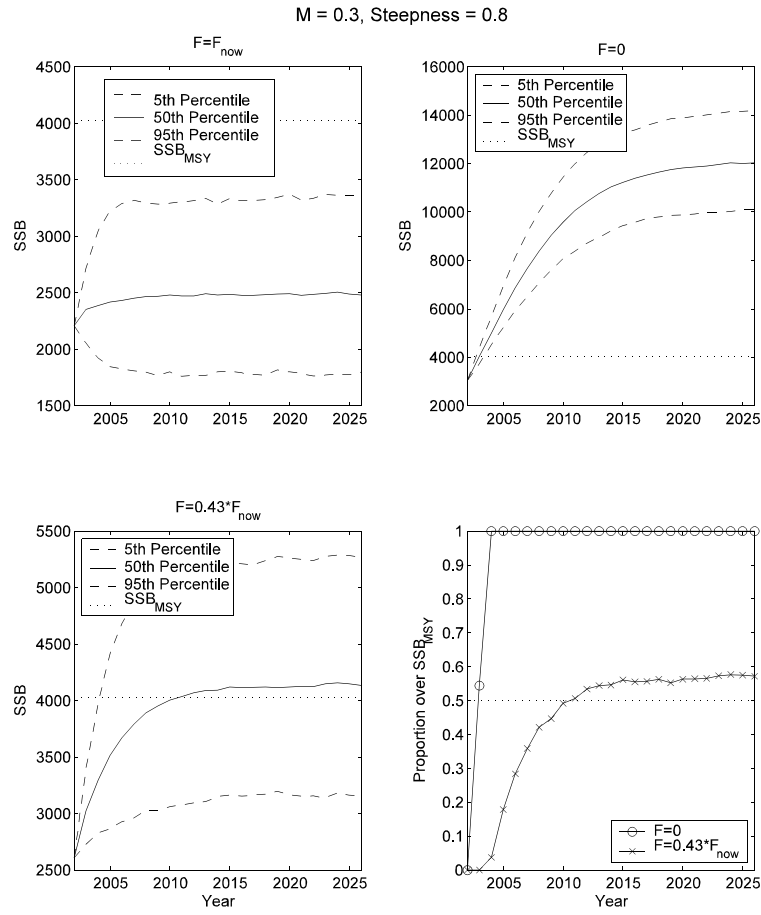


Figure E.5. SSB projections for $M = 0.3$, steepness = 0.8. F_{rebuild} is $F = 0.43 \cdot F_{\text{now}}$.

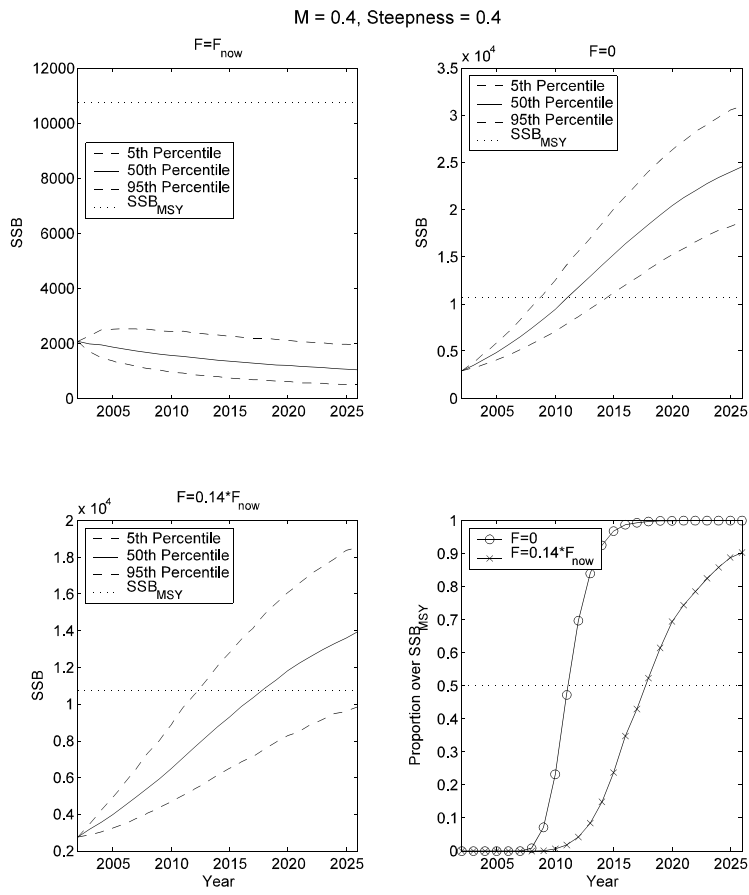


Figure E.6. SSB projections for $M = 0.4$, steepness = 0.4. F_{rebuild} is $F = 0.14 * F_{\text{now}}$.

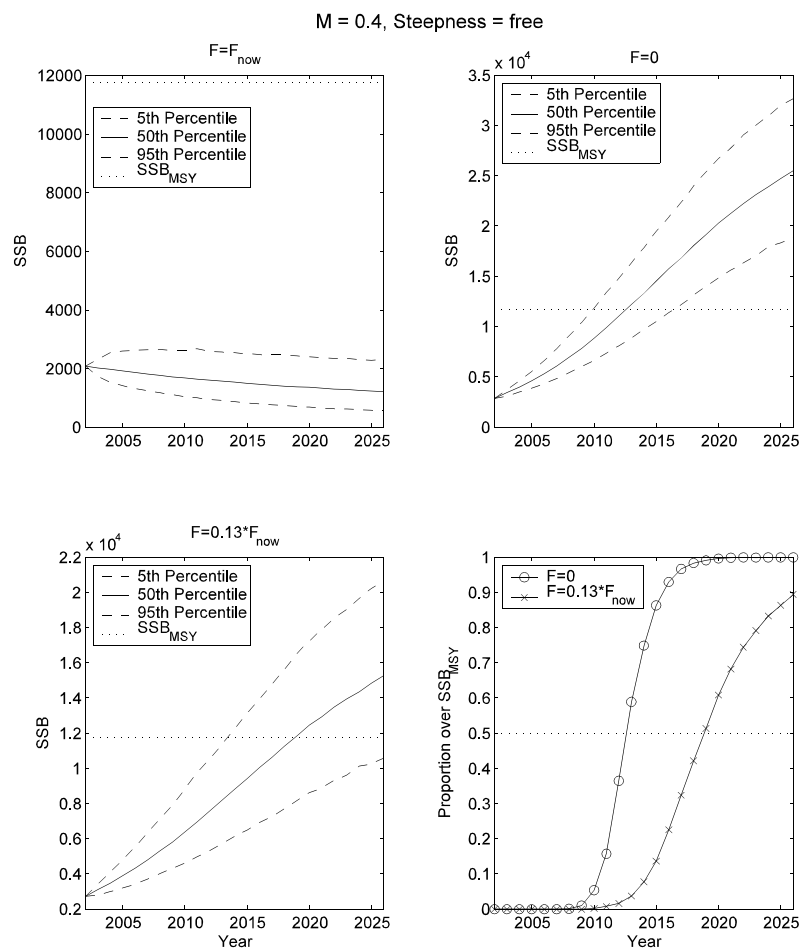


Figure E.7. SSB projections for $M = 0.4$, steepness = free. F_{rebuild} is $F = 0.13 * F_{\text{now}}$.

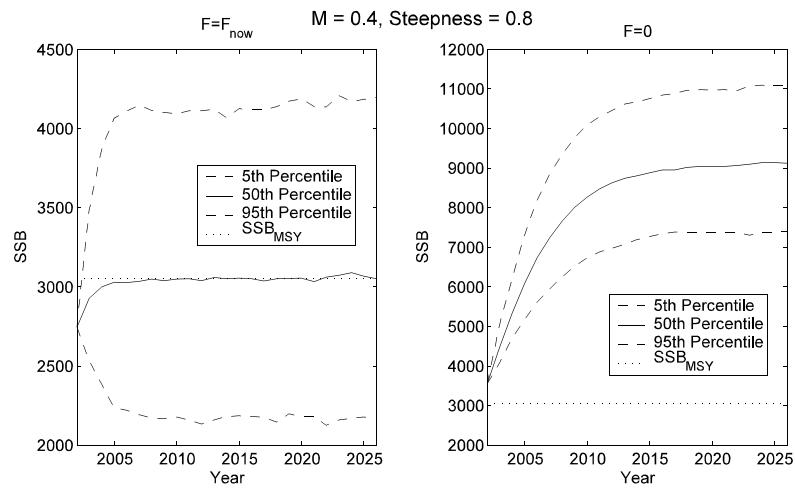


Figure E.8. SSB projections for $M = 0.4$, steepness = 0.8. No rebuilding required.

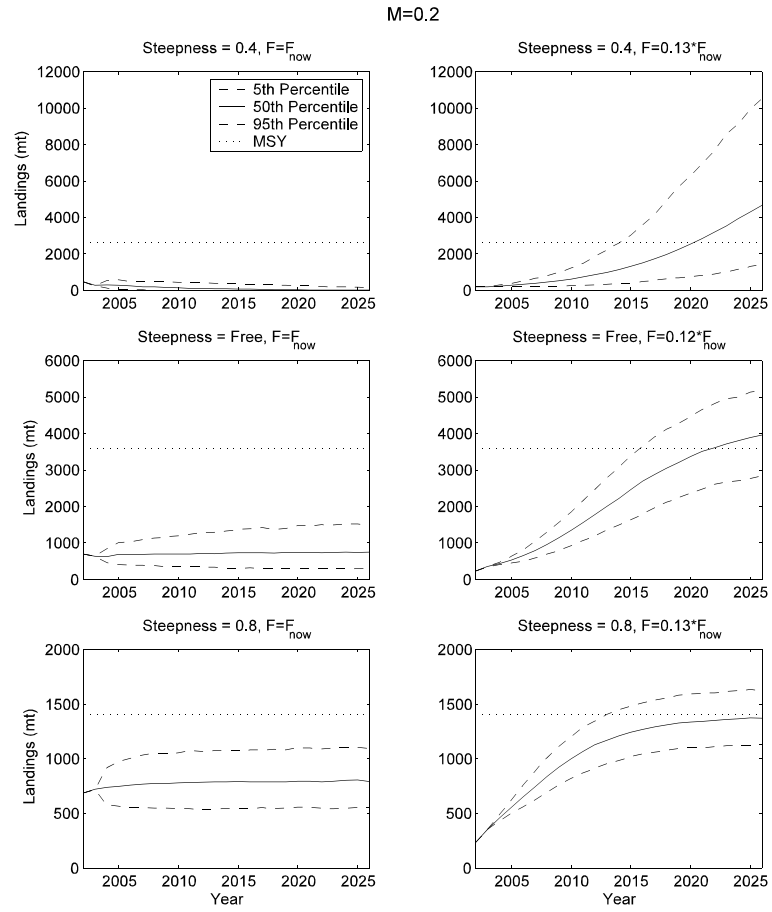


Figure E.9. Projected landings with $M=0.2$. Left column: $F = F_{now}$. Right column: $F = F_{rebuild}$ expressed as a proportion of F_{now} .

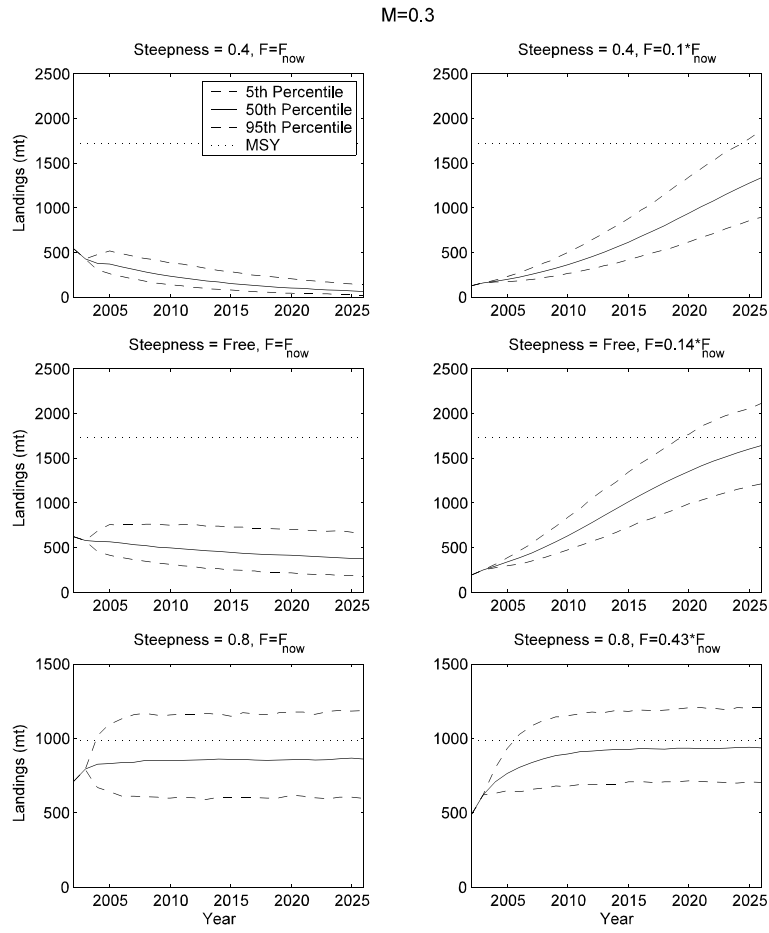


Figure E.10. Projected landings with $M=0.3$. Left column: $F = F_{now}$. Right column: $F = F_{rebuild}$ expressed as a proportion of F_{now} .

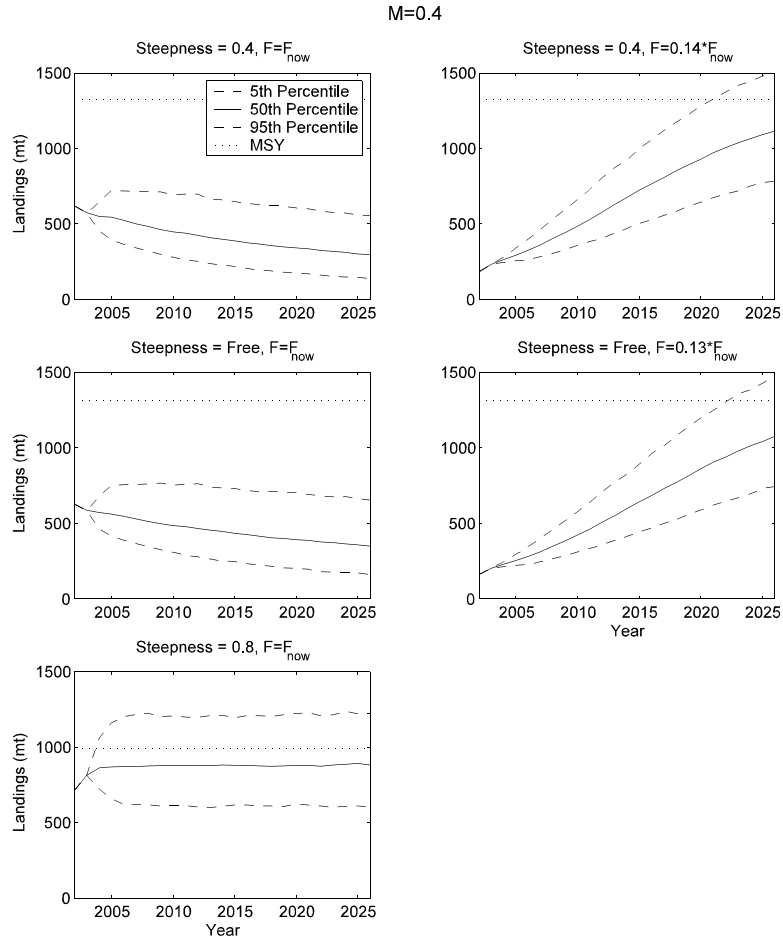
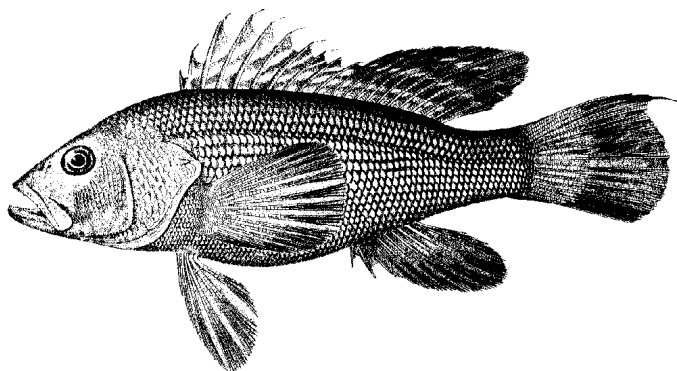


Figure E.11. Projected landings with $M=0.4$. Left column: $F = F_{\text{now}}$. Right column: $F = F_{\text{rebuild}}$ expressed as a proportion of F_{now} . No rebuilding was required for the case of steepness = 0.8.

Appendix F. Summary of Mid-Atlantic Black Seabass Status

(Appended PDF file provided by Gary Shepherd)



Last Revised: January 2000

[Summary Status](#)

[Landings and Abundance Trends](#)

[Landings Data](#)

Black Sea Bass

by
Gary Shepherd

Black sea bass, *Centropristis striata*, occur along the entire U.S. Atlantic coast. Two stocks have been recognized, one north and the other south of Cape Hatteras, North Carolina. The northern group winters along the 100 m (55 fathom) depth contour off Virginia and Maryland, and then migrates north and west into inshore waters, where it becomes associated with structured bottom habitat (reefs, oyster beds, and wrecks, for example).

Spawning begins in March off North Carolina and occurs progressively later (until October) further north. Most black sea bass begin life as females and later transform into males, and most individuals (both sexes) attain sexual maturity by age 3. Transformation from female to male generally occurs between ages 2 and 5. Females are rarely found older than 8 years (>35 cm or 14 in.), while males may live up to 15 years (>60 cm or 24 in.). Black sea bass are omnivorous, feeding on crustaceans, molluscs, echinoderms, fish, and plants.

The principal commercial fishing gears used to catch black sea bass are otter trawls and fish pots. Recreational fishing is significant. Black sea bass are managed under Amendment 12 to the Summer Flounder Fishery Management Plan or FMP (now known as the Summer Flounder, Scup, and Black Sea Bass FMP). Management measures under the FMP include a moratorium on new permits, gear restrictions and minimum fish sizes, a coastwide commercial quota and a recreational harvest limit.

Total nominal catch north of Cape Hatteras decreased from 4,300 mt in 1996 to 1,800 mt in 1998. Commercial landings fluctuated around 2,600 mt from 1887 until 1948 and then increased to 9,900 mt in 1952 before declining to only 600 mt in 1971. Between 1980 and 1993, commercial landings averaged 1,500 mt per year. Landings averaged 1,100 mt between 1994 and 1997 and totaled 1,200 mt in 1998. Landings since 1998 have been restricted by quota regulations. There has been no foreign fishing on this stock other than for a reported catch of 1,500 mt by distant-water fleets in 1964.

Estimated recreational landings, occurring primarily in the middle Atlantic states, are comparable in magnitude to those from the commercial fishery. Recreational landings averaged 2,000 mt per year between 1981 and 1997, and accounted for 31 to 79% of the total annual landings of black sea bass during those years. Recreational landings declined to 600 mt in 1998, a 68% decline from 1997. The decrease was partially attributable to an increase in minimum size from 9 in. to 10 in. total length.

The NEFSC spring bottom trawl survey biomass index increased during the early 1970s, peaking in 1977, but declined sharply between 1979 and 1982 to record-low levels. The index has increased somewhat since 1997 suggesting increased levels of biomass. Young of year (age 0) indices from the NEFSC autumn bottom trawl survey indicate that above-average year classes occurred in 1985, 1986, 1994 and 1995. Recruitment in 1999 appeared to be above average. Size composition data from commercial landings indicate that black sea bass recruit fully to the trap and trawl fisheries by ages 2 and 3, respectively.

Definitive estimates of fishing mortality are not available for 1998. Survey index values have increased somewhat in recent years, but remain well below the minimum biomass threshold (0.9 kg/tow). The stock is overfished and at a low biomass level.

For further information

Musick, J. A. and L. P. Mercer. 1977. Seasonal distribution of black sea bass, *Centropristis striata*, in the Mid-Atlantic Bight with comments on the ecology of fisheries of the species. *Trans. Am. Fish. Soc.* 106(1):12-25.

NEFSC [Northeast Fisheries Science Center]. 1997. [Report of the] 25th Stock Assessment Workshop (25th SAW), Stock Assessment Review Committee (SARC) consensus summary of assessments. *Northeast Fish. Sci. Cent. Ref. Doc.* 97-14:143p.

Shepherd, G. R. and J. S. Idoine. 1993. Length-based analyses of yield and spawning stock biomass per recruit for black sea bass, *Centropristis striata*, a protogynous hermaphrodite. *Fish. Bull.*, U.S. 91:328-337.

Summary Status

Long-term potential catch (MSY)	=	Unknown
Biomass corresponding to MSY	=	Unknown
Minimum biomass threshold ¹	=	0.9 kg/tow
Stock biomass in 1998	=	0.3 kg/tow (Implies an overfished condition)
F_{MSY}^2	=	$F_{MAX} = 0.32$
F_{TARGET}	=	F associated with quota
Overfishing definition	=	F_{MSY}
F_{1998}	=	Unknown
Age at 50% maturity	=	2 years
Size at 50% maturity	=	19.0 cm (7.5 in.), males 19.1 cm (7.5 in.), females
Assessment level	=	Index
Management	=	Summer Flounder, Scup, and Black Sea Bass FMP

M = 0.20 F_{0.1} = 0.18 F_{max} = 0.32

¹ Maximum 3 year moving average of NEFSC Spring Survey exploitable biomass index (fish>22cm)

² F_{MAX} is used as a proxy for F_{MSY}

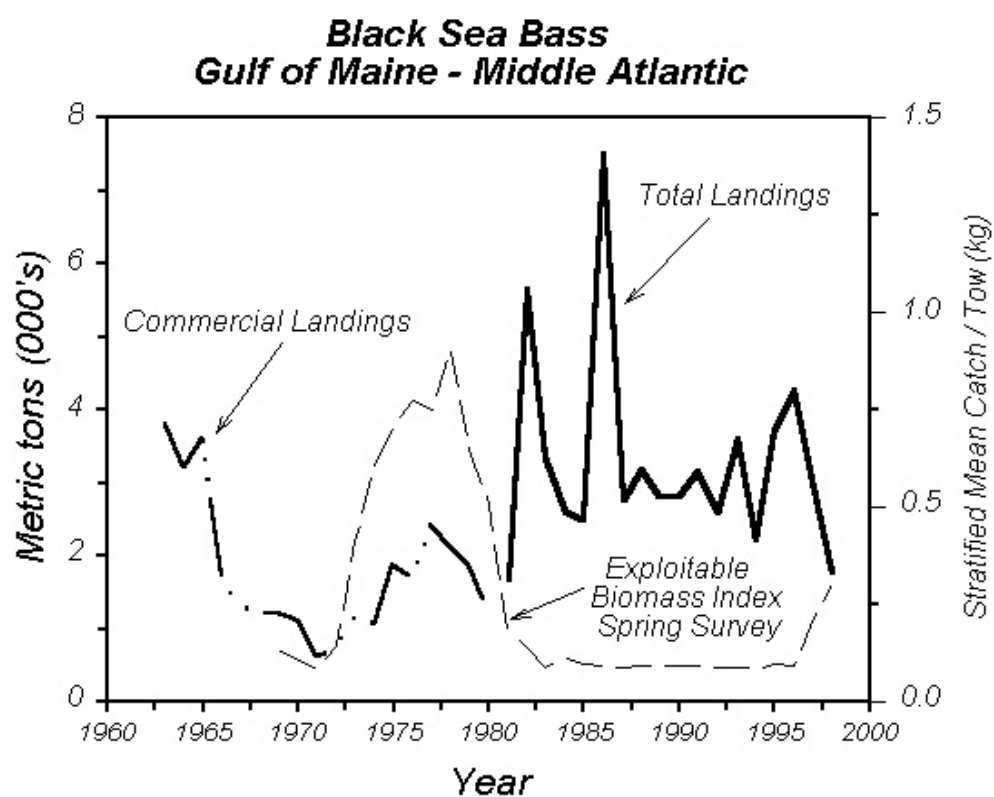


Table 15.1
Recreational and commercial landings (thousand metric tons)

	Year										
Category	1981-88	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
	Average										
United States	1.6	1.3	1.6	1.3	1.4	1.4	0.9	0.9	1.5	1.2	1.2
Canada	-	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-	-
Total nominal catch	3.6	2.8	2.9	3.2	2.6	3.6	2.2	3.7	4.3	3.1	1.8